PUBLIC PERCEPTION OF NUTRITIONAL HAZARDS

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Public perception of nutritional hazards

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Summary

Nutrition is recognized as a significant and modifiable determinant of health. Statistics in many countries show growing rates of nutrition-related diseases, including heart disease, type 2 diabetes and cancer. In order to tackle this problem, health experts are concerned with raising consumers' awareness of overnutrition and the necessity to change nutrition behaviour.

Consumers have varying ideas about how food affects their health. These ideas often differ from health experts' opinions and priorities. Some consumers are worried about synthetic chemicals in their diet, others about bacteria, and yet others about calories. To design effective communication on nutrition, it is necessary to know how consumers develop their ideas on the link between food and health.

This research aims to examine Swiss consumers' perceptions of over and malnutrition, synthetic chemicals in food, and bacteria. Special attention has been given to identifying the factors that shape these perceptions. Among these factors, knowledge plays a special role as it is historically seen as a key factor of nutrition behaviour. The research also aims to evaluate the relationships between hazard perceptions, knowledge and nutrition behaviour. The final goal is to develop ideas for future health communications that may support their effectiveness.

Six research studies were conducted to pursue the present research aims. Data were collected through three written public surveys that assessed consumers' risk perceptions of food hazards, the factors shaping these perceptions and nutrition behaviour. Different multivariate statistical techniques, including structural equation modelling, regression analyses and analyses of variance were used to answer specific research questions. New instruments to assess consumers' knowledge of healthy diets, additives, pesticides and bacteria in food were developed using a combination of qualitative and quantitative methods.

The results showed that consumers had knowledge gaps in specific aspects of over and malnutrition. For instance, consumers showed misconceptions about the food pyramid that may lead to over nutrition. Knowledge gaps were also observed in other hazard areas that were investigated. In all hazard areas, these knowledge gaps were related to nutrition behaviour: lower knowledge implied risk-enhancing behaviour. This relationship was, however, limited. Other, more affective factors such as general attitudes towards chemicals, perceived benefits from food technology or social trust also influenced risk perceptions and nutrition behaviour. The strength of these influences varied according to the hazard in question. Moreover, the moderate explained part of variance in nutrition behaviour indicated the influence of factors not included in the present research.

In a study investigating the environmental chemical phthalates, a surprising finding was made on the relationship between risk perceptions and behaviour: higher risk perceptions implied higher exposure to phthalates through food consumption.

In conclusion, the present research shows that in addition to knowledge, other factors determine consumers' perceptions of the nutritional hazards of over and malnutrition, food additives, pesticides and bacteria. These factors need to be taken into account when designing nutrition communication.

Chapter I

General Introduction Into Nutritional Hazards and Their Public Perception

1 Introduction

"Lack of minerals or vitamins is easily treatable, isn't it? (…) But all the others, heart disease, diabetes, cancer, they are actually… These are all disasters. One by one. These are all serious things." Peter, 58-years-old, computer hardware specialist.

"I avoid refined foods. And those with I-don't-know-how-many additives. Or preserved ones. I would never buy a UHT milk. I'd rather have no milk at all than that sort of thing." Elisabeth, 54-years-old, mediation specialist.

"Sometimes I have problems with my digestion. I trace this back to an infection with salmonella during my childhood. Salmonella are very aggressive and I could imagine that they damaged my intestinal flora.

"I avoid doughnuts because they contain nothing that goes even into the direction of being healthy. They consist of white flour, which makes you hungry quickly, and a huge amount of sugar, which changes into fat. I have the feeling the next day, I will have five more spots on my face and weigh half a kilo more. But sometimes I just feel like eating one and then I do it anyway." Natalie, 27-years-old, graphic designer.

"I believe in scientific research. I believe there really are fungi that are cancerous. It is known that certain foods should not be consumed. For example, jam with fungus. Or other foods that have been kept for too long and that developed fungi." Hanna, 27-years-old, communication specialist.

"With plant products, those that have been grown in unnatural conditions carry a potential risk: stuff grown in greenhouses, extremely treated with poisons, or genetically modified or otherwise changed or influenced." Sebastian, 31-years-old, student.

"I try not to buy any ready-made foods. They contain many preservatives, colourings and hidden fats. (…) It is very important to me to buy natural foods." Tina, 37-years-old, policewoman.

All living beings need to eat. Food is essential for metabolism, growth and activity. In the last fifty years, modern agriculture, storage and transporting technology have led to an abundance and diversity of available foods, independent of season. These innovations have turned food into a commodity. No longer do we consume food purely for survival, we now have preference, attitude and pleasure influence our eating habits. On the negative side, however, food is increasingly recognized as a determinant of illness. Obesity and other nutrition-related diseases have become a public concern in many countries (World Health Organization, 2003).

As the statements above illustrate, people have very different views about the way in which food may affect health (Dickson-Spillmann, 2008). Some people attribute the health effects to sugar and fat, while others refer to colourings or pesticides, and yet others to salmonella and fungi. Bits of scientific knowledge mingle with laypeople's ideas about food and health.

In the light of the obesity epidemic it appears important to systematically investigate consumers' concerns about nutrition, and the origin of these concerns. This is the context in which the present research is located. We depart from the idea that if consumers invest worry and expense into minor objective risks, they might inadvertently expose themselves to other, more serious health risks, such as obesity. If we know consumers' understanding of food risks, we are able to develop appropriate communications in order to provide consumers with a balanced view of nutritional risks.

For a better understanding of the present document, a few terms need to be defined. Firstly, there is a distinction between *food* (or *foodstuff*), *nutrition* and *diet*. Food refers to a substance intended for human consumption. Nutrition is the process by which living organisms take in and use food for the maintenance of life (Geissler & Powers, 2005). Diet describes the selection of foods usually consumed by a person. Despite having different definitions, food and nutrition (and sometimes, diet) will be used interchangeably throughout the present work.

Two further definitions to introduce are those of *risk* and *hazard*. In the literature, risk is defined in a statistical sense as the product of the probability of an event multiplied by its consequences. Meanwhile, hazard describes a potential to cause harm; a "threat to people and the things they value" (Kates & Kasperson, 1983). The concept of hazard is broader than risk and therefore more suitable in the context of the present research. Nevertheless, the two terms will not be strictly distinguished. *Risk* (or *hazard*) *perception* refers to "people's beliefs, attitudes, judgments and feelings (…) towards a hazard" (Pidgeon, 1992, p. 89).

The following chapter will provide an overview of the nutritional hazards dealt with in the present work. Thereafter, the current state of research on consumers' perceptions of nutritional hazards will be introduced. Factors shaping these perceptions that are relevant for the present research studies will be named. To conclude, a summary will be provided, the aims of the present research will be defined, and an overview of the studies undertaken will be given.

2 Nutritional Hazards

The present work deals with three categories of nutritional hazards. The first category includes hazards related to over and malnutrition, the second category includes hazards related to chemicals, and the last category includes microbiological hazards. In the following chapters, each hazard category will be described in more detail.

2.1 Overnutrition and Malnutrition

A healthy nutrition, often described as a balanced diet, contains the essential nutrients in appropriate quantities required for growth and maintenance of health (Anderson, 2005). Such nutrition is low in saturated fats and transfats, cholesterol, added sugars, salt and alcohol and high in fruit and vegetables.

Overnutrition can either refer to the intake of energy, to the individual components of energy (e.g. sugar, fat) or to the micronutrients (Seidell & Visscher, 2004). Here, overnutrition will refer to energy intake to describe an imbalance between intake and expenditure. Excessive energy intake over a longer period of time can result in weight gain, overweight and obesity. Obesity is associated with a higher incidence of metabolic syndrome, type 2 diabetes mellitus, cardiovascular disease, cancer, osteoarthritis and respiratory disorders (Seidell & Visscher, 2004).

Malnutrition refers to a diet that does not meet the normal needs for specific nutrients (Manary & Solomons, 2004). While deficits of macronutrients occur mainly in developing countries, deficits of micronutrients are an increasing concern in developed countries. Where macronutrient intake is sufficient to meet energy needs, micronutrient deficiency may still exist as the food consumed is of a low nutrient density (Manary & Solomons, 2004). Thus, while overnutrition is a problem of consumption volume (*how much* is eaten), malnutrition is a problem of food choice (*what* is eaten).

In most European countries including Switzerland, diet-related diseases have been increasing over the past years (World Health Organization, 2003). In Switzerland, 37.1% of inhabitants are either overweight or obese. The total costs resulting from healthcare and loss of productivity due to overweight, obesity and associated illnesses were calculated at 2,691 million Swiss Francs (Schneider & Schmid, 2004).

The WHO has attributed the rise of obesity to a “nutrition transition” that involves a shift from largely plant-based diets to high-fat, energy-dense diets with a substantial content of animal-based foods (World Health Organization, 2003). The modernisation of agriculture, higher incomes and improved infrastructures through urbanisation, including cold chains, are the reasons for this shift (Nishida & Mucavele, 2004-2005; World Health Organization, 2003). This transition is accompanied by increasingly sedentary lifestyles.

The role of psychological factors in consumption volumes and choice of healthy and unhealthy foods has been extensively investigated. Nutrition knowledge is one factor that has been examined (e.g. Shepherd & Towler, 1992; Wardle, Parmenter, & Waller, 2000). Further, the sensory appeal, familiarity and habit, risk perceptions (e.g. of pesticides), personal ideologies such as vegetarianism, animal welfare or the subjective importance of health play a role (Kirk, Greenwood, Cade, & Pearman, 2002; Pollard, Kirk, & Cade, 2002). Evidence indicates that environmental factors, such as the price, advertising, size of food packages, variety of food assortments and the shape of plates may also influence consumers’ food choices and consumption volumes (Pollard, et al., 2002; Wansink, 2004). Further, there is evidence of an association between certain sociodemographic variables such as education or gender and food choice (Johansson, Thelle, Solvoll, Bjorneboe, & Drevon, 1999). Even genetic factors, such as the ability to taste bitterness, may account for certain food choices (Pollard, et al., 2002).

2.2 Chemicals

Foods naturally consist of chemicals. There may, however, be chemicals present in food products that are not naturally part of them. These chemicals enter the food product in various ways, some controlled, others uncontrolled; some desired, others undesired; some natural, others synthetic. The present work deals with food additives, pest control products and environmental chemicals, which vary along these dimensions.

2.2.1 Food Additives

Food additives are defined in the EU Community legislation as “any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food whether or not it has nutritive value, the intentional addition of which to food for a technological purpose … results ... in it or its by-products becoming directly or indirectly a component of such foods" (European Economic Community, 1988, p. 3). Some additives have been used for centuries, such as in the preservation of foods by pickling or using sulphur dioxide in wines. With the advent of processed foods, new additives have been introduced. Additives serve various purposes (Shibamoto & Bjeldanes, 2009):

- To maintain product consistency: emulsifiers, stabilisers, thickeners
- To improve nutritional value: vitamins, minerals
- To maintain palatability and wholesomeness: preservatives
- To provide leavening
- To control acidity
- To enhance flavour
- To impart desired colour

Additives can be made of synthetic or natural materials. They are added to food in a scientifically controlled manner and their use underlies strict regulation (Shibamoto & Bjeldanes, 2009). The panel on food additives and nutrient sources added to food (ANS) of the European Food Safety Agency (EFSA) carries out risk assessments in order to produce scientific opinions and advice for risk managers and legislators. The EFSA supports the European Union (EU) in issuing directives concerning the use of additives in foods (European Economic Community, 1994a, 1994b, 1995). Substances that are not explicitly mentioned in the directives are banned. Each permitted additive is regarded as harmless and assigned an E-number. Additives in a food product have to be labelled on food packaging (http://ec.europa.eu/food/fs/sfp/flav_index_en.html; European Community, 2008a; European Economic Community, 2000). The EU also passes directives regarding authorisation and control procedures for additives in foods. In organic foods, all usage of additives is to be avoided as far as possible. Only substances obtained through physical separation processes, cooking processes and fermentation are permitted as additives (European Community, 2007, 2008b).

2.2.2 Pesticides

Pesticides are substances that prevent or control the damage caused by a pest. Therefore, they support abundance and diversity in the food production process (Shibamoto & Bjeldanes, 2009; Sumner & Eifert, 2002). Pesticides are divided into several groups:

- Insecticides to kill noxious insects
- Herbicides to prevent growth of weeds
- Fungicides to protect crops from fungi
- Rodenticides for the control of rodents
- Bactericides for the control of bacteria

The use of pesticides in agriculture and the environmental pollution due to industrial emission during their production have resulted in the occurrence of pesticide residues in food commodities, water and soil (Ahmed, 2001). The toxic effects of pesticides on humans and other organisms and the ecological consequences of pesticide contamination of groundwater and soil have been discovered relatively recently (Shibamoto & Bjeldanes, 2009). The effective health risk through exposure depends on whether the specific pesticide accumulates in the body. Experimental studies show that pesticides that accumulate may have varied health effects including neurological symptoms or progressive muscle weakness (Shibamoto & Bjeldanes, 2009).

Before a pesticide product is permitted for agricultural use it must undergo toxicological testing. The EFSA is responsible for conducting the safety tests of pesticides. Based on these tests the level of pesticide residuals that is permitted in food (*maximum residue level*, MRL) is determined (Europäische Kommission & Generaldirektion Gesundheit und Verbraucher, 2008; European Community, 2005). The responsibility for controlling the pesticide levels in food lies with the authorities of the EU member states. Switzerland has adopted the MRLs of the EU (Bundesamt für Gesundheit, 2010). The Swiss Federal Office of Public Health states that "a health risk through pesticide residuals is unlikely" (Bundesamt für Gesundheit, 2006). Organic farming in Switzerland does not allow the use of synthetic pesticides while natural substances are permitted (Forschungsinstitut für biologischen Landbau, 2010).

2.2.3 Environmental Chemicals

Industrial activities in the modern era have led to the deposition of various potentially hazardous substances in the environment through ignorance, accident and irresponsibility (Shibamoto & Bjeldanes, 2009). These substances have entered the food chain. Foods can also be accidentally contaminated with chemical substances at the various stages of their production, packaging, transport or storage (European Community, from http://ec.europa.eu/food/food/chemicalsafety/contaminants/index_en.htm).

The most widely studied unintended substances in food are polychlorinated biphenyls, dioxins and heavy metals (lead, mercury and cadmium). Exposure to environmental chemicals is associated with varied health effects such as endocrine disruption, cancer, chloracne, muscular weakness, liver enlargement, anemia and disorders of the central nervous system, although data on health effects in humans are limited (Sharpe & Irvine, 2004; Shibamoto & Bjeldanes, 2009).

The Panel on contaminants in the food chain (CONTAM) of the EFSA issues scientific opinions on the safety of environmental chemicals in food and determines levels of contamination that may be considered safe. The EU member states carry out random contamination checks of food products. If a risk is identified, they must inform the other member states and production or distribution of contaminated products may be temporarily suspended or restricted (European Commission & Health and Consumer Protection Directorate-General, 2008). Switzerland has adopted the maximum intake levels determined by the EFSA (Bundesamt für Gesundheit, 2008).

Environmental chemicals in the soil cannot be avoided. Therefore, they are equally present in organically and conventionally grown foods. The presence or absence of environmental chemicals in food depends mainly on farm location (Magkos, Arvaniti, & Zampelas, 2003).

2.3 Bacteria

Bacteria are a natural component of most foods. The most frequent bacteria in food are campylobacter, salmonella and *Escherichia coli*. The main determinants of the occurrence of bacteria in food are the PH value and the availability of water. The most important external factor is the air temperature (Montville & Matthews, 2008). Meat, dairy, fruit and vegetables are especially prone to contamination. In 2008, in EU member states the prevalence of campylobacter-colonised broiler batches was 71.2% and that of campylobacter-contaminated broiler carcasses was 75.8% (European Food Safety Agency, 2010). Bacteria similarly affect organic and conventionally produced foods (Montville & Matthews, 2008).

Infections with foodborne bacteria usually result in gastrointestinal symptoms such as diarrhoea and vomiting. In Europe, salmonella and campylobacter dominate bacterial foodborne diseases (European Food Safety Agency, 2010). In recent years, a rise of notified foodborne diseases has been reported in Europe and the USA. In Switzerland, statistics show that the number of reported salmonella infections slightly dropped between 2004 and 2009 from 1,900 to 1,100 annual cases, while campylobacter infections increased from 5,300 to over 7,700 cases. During the same period, infections with E. Coli and listeria stayed at a low level of around 50 cases per year (Bundesamt für Gesundheit, from http://www.bag.admin.ch/k_m_meldesystem/00733/00804/index.html?lang=de).

Factors contributing to the rise in numbers of food poisonings include microbial drug resistance, new procedures for intensive rearing and slaughtering of animals and birds, changes in retailing practice and in social and household patterns of shopping and eating, increased global trade and travel and changes in notification systems (Miles, Braxton, & Frewer, 1999).

The most important source of bacterial infections, however, is the domestic kitchen. In the EU, 92% of cases of campylobacteriosis for which information on importation status was available, were domestically acquired (European Centre for Disease Prevention and Control, 2010). Thus, the key to prevention of foodborne infections is consumers' behaviour in their own kitchen. Cool storage, freezing, heating, using clean kitchen equipment, separating raw and cooked foods as well as hand decontamination help to avoid bacterial growth in foods and cross-contamination of other foods. Health authorities have prepared leaflets for consumers containing instructions to prevent bacterial growth. The WHO poster "Five Keys to Safer Foods" has been translated into more than 60 languages (World Health Organization, from http://www.who.int/foodsafety/publications/consumer/5keys/en/).

3 Consumers' Food Hazard Perception

When European consumers were asked for the most important factor influencing their food choices, 14% responded "my family's/ own health". Thus, health ranked fifth in consumers' food choice motives after quality, price, appearance, and taste. In light of the growing evidence of health effects from food consumption, there lies an interest in examining consumers' perceptions of the food-health link. When European consumers were asked to spontaneously associate food with risks, roughly equal numbers named "food poisoning" (16%), "chemicals/ pesticides/ toxic substances" (14%) or "overweight, obesity" (13%) (European Commission, 2006). In the present chapter, the question is, how are people's perceptions of nutritional health hazards formed?

3.1 Qualitative Dimensions of Consumers' Food Hazard Perception

People who have no expertise in a specific field (*laypeople*) often rate risks differently from experts in that field. Experts' fatality estimates correlate highly with technical estimates of fatalities, which are based on the multiplication of the probability of an event with the severity of the consequences of that event (Slovic, 1987). Research suggests that laypeople's estimates are not based on such quantification, but that qualitative factors play an important role. To identify these factors, a methodology called the *psychometric paradigm* has been used (Slovic, 1987). Within this paradigm, laypeople are asked to rate a number of hazards regarding characteristics such as dread, voluntariness of exposure, extent of knowledge to science or likelihood of fatalities. The data matrix (Hazards x Rating scales) is then subjected to a principal component analysis (PCA).

The psychometric paradigm has been used to study laypeople's perception of food hazards (Fife-Schaw & Rowe, 1996; Siegrist, Keller, & Kiers, 2006; Sparks & Shepherd, 1994). One factor that repeatedly resulted from PCA was labelled as Unknown. This factor incorporated aspects such as the extent to which a hazard is known to those exposed, or known to science. Hazards scoring high on this dimension are genetically modified (GM) organisms, a hazard scoring low on this dimension is excessive calorie intake. Food additives are perceived as moderately unknown. Another factor emerging from PCA was the Severity associated with the hazard (Fife-Schaw & Rowe, 1996; Sparks & Shepherd, 1994). High-severity hazards cause people to worry, to perceive a threat for future generations, and are perceived as likely to cause harm to those exposed. Pesticides, environmental contamination or salmonella score high on this dimension, vitamin C deficiency scores low. Siegrist et al.'s (2006) factor Dread risk shows similar characteristics and hazard scores to the Severity factor identified in the other studies.

3.2 Optimistic Bias and Perceived Control

People tend to underestimate their own susceptibility to a risk event, compared to their peers' susceptibility. This tendency has been labeled as *optimistic bias* (Weinstein, 1980). One of the proposed explanations of optimistic bias is that people perceive to have control over the hazard. This explanation is supported by the observation that optimistic bias is particularly strong with lifestyle-associated hazards such as calorie intake or alcohol consumption (Frewer, Shepherd, & Sparks, 1994; Sparks & Shepherd, 1994), which both are perceived as controllable by consumers. The consequences of optimistic bias are problematic for hazard communication. People who do not see themselves at risk might not be receptive to communication, despite exposing themselves to the risk (Sparks & Shepherd, 1994).

3.3 Heuristics

Heuristics are defined as the mental shortcuts people use to make judgments quickly and efficiently (Aronson, Wilson, & Akert, 2004). In the food context, the *availability heuristic* plays a role in consumers' hazard perception. According to this heuristic (Tversky & Kahneman, 1973), an event will be perceived as more likely if instances of it are easily recalled or imagined (i.e. readily available in memory). This heuristic has been used to explain why respondents deliver more accurate fatality estimates regarding less vivid, imaginable causes of death such as diabetes, as compared to more imaginable deaths such as botulism, where overestimation of fatalities frequently occurs.

3.4 Benefit Perception

From an analytic viewpoint, risks and benefits associated with a hazard are distinct factors that tend to be positively correlated (Finucane, Alhakami, Slovic, & Johnson, 2000). Laypeople, however, often perceive risks and benefits to be inversely related: the higher the risk, the lower the benefit (Alhakami & Slovic, 1994). The perception of benefit may have a stronger impact on the acceptance of certain food products than the perception of risk. This is supported by the finding that the perceived benefit of GM foods had a stronger influence on GM acceptance than the perceived risk (Siegrist, 2000).

3.5 Trust

When consumers have little knowledge about a hazard, they rely on social trust in order to make decisions about their exposure to the hazard (Siegrist & Cvetkovich, 2000). For example, consumers with higher trust in institutions or in persons doing genetic modification research showed lower risk perceptions, and higher benefit perceptions of GM food products (Siegrist, 2000). Thus, trust is particularly relevant in the context of food technologies, about which not much knowledge is available to laypeople. Trust appears to be based on values shared with the source. If an institution's behaviour is judged to reflect a person's values, the institution is seen as trustworthy (Siegrist, 2008).

3.6 Attitudes

Attitudes are defined as evaluations of people, objects or ideas. They have an affective, a cognitive and a behavioural component and may result in positive or negative reactions (Aronson, et al., 2004). Attitudes direct attention, processing and evaluation of new information (Eagly & Chaiken, 1993). In the food context, an area in which attitudes have been consistently linked to hazard perception is natural foods. People with more positive attitudes towards organic fruit and vegetable saw higher risks and lower benefits associated with the use of pesticides (Saba & Messina, 2003). Similarly, people who prefer natural foods are more suspicious toward new foods and food technologies (Huotilainen & Tuorila, 2005), and general environmental attitudes influenced attitudes toward GM foods (Siegrist, 1998).

3.7 Knowledge

The observation that laypeople and experts rate risks differently suggests that scientific knowledge about the risk field might modify risk perceptions. Knowledge can be assessed as either subjective or objective knowledge. Subjective knowledge is the extent to which an individual feels to be familiar with the hazard. Objective knowledge is assessed through a series of statements about the hazard that can be evaluated in terms of *correct* or *incorrect*.

Empirically, associations between knowledge and risk perception have been ambiguous. These associations seem to depend on various aspects. The first aspect is the specific hazard. For example, the higher the knowledge of pesticides, the higher the perceived risk, but there was no such relationship for food irradiation (Frewer, et al., 1994). The second aspect is whether perceived risk refers to the individual, to other people or to society. When respondents had to rate risk of food poisoning for themselves, a negative relationship between knowledge and risk perception was observed, whereas no such relationship was observed when risk for other people or society had to be rated (Frewer, et al., 1994). Finally, the relationship between knowledge and risk perception depends on whether objective or subjective knowledge is assessed. While there was no relationship between objective knowledge of GM organisms and acceptance of GM organisms in food, there was a positive relationship between subjective knowledge and acceptance (House et al., 2004).

Further to risk perception, knowledge also shows an ambiguous relationship with risk-related behaviour such as the consumption of healthy and unhealthy foods. Intervention studies in specific target groups have shown that enhancing nutrition knowledge can modify nutrition behaviour (e.g. Klohe-Lehman et al., 2006). In contrast, nutrition knowledge studies in the general population have either shown weak or no relationships to nutrition behaviour (e.g. Wardle, et al., 2000).

3.8 Individual Experience

Personal experience may shape the perception of nutritional hazards. Individuals who had experienced food poisoning showed less optimistic bias regarding food poisoning in their own home than individuals who had not experienced food poisoning (Parry, Miles, Tridente, Palmer, & South and East Wales Infectious Disease Group, 2004). One study compared the impact of personal experience on the concern evoked by a number of hazards (Barnett & Breakwell, 2001). The hazards varied according to whether they were perceived as voluntary or involuntary. Among the involuntary hazards were "foods containing food colouring" and "GM foods", among the voluntary hazards were "eating beef" and "drinking alcoholic drinks". The results showed that the frequency with which a hazard had been experienced, the perceived size of its impact (*tiny* to *huge*) and its perceived outcome (*very negative* to *very positive*) influenced concern about involuntary, but not voluntary hazards. With increasing frequency and impact, concern increased; with more positive perceived outcome, concern decreased. Although these effects were small, they illustrated the influence of individual experience on hazard perception- at least in relation to hazards perceived as involuntary.

3.9 Social Amplification of Risk

The social amplification of risk theory explains why apparently minor risks or events can produce massive public reactions with social and economic consequences (Kasperson et al., 1988). The theory describes how psychological, social, institutional, and cultural processes may amplify (or attenuate) public perceptions of a hazard. The theory is based on the sender-receiver model of classic communication theory (DeFleur, 1966). The theory assumes that both sender and receiver can amplify the signal (i.e. the message) that is passed between them. The sender (e.g. news media, public agencies or risk management institutions) may amplify by filtering, selecting, repeating, emphasizing the credibility of spokespeople or by dramatizing. The receiver can amplify by using heuristics to draw inferences, stigmatizing, or using the signal value of a message. As a secondary consequence, social amplification of risk can provoke behavioural responses such as avoidance of risk-related activities or products, or application of political and social pressure. Behavioural responses may also spread to similar activities or products, distant locations or future generations (ripple effect). Despite the theory's obvious potential to explain the "food scares" that have occurred in the past decades (e.g. bovine spongiform encephalopathy (BSE), E. Coli, salmonella, dioxin residues) (Knowles, Moody, & McEachern, 2007), empirical examinations are sparse. Frewer, Miles and Marsh (2002) found support for the theory in relation to changes in perceptions of GM foods through media reporting.

4 Summary

Foods bear many potential hazards. These hazards can arise from natural factors, such as the calorie content or bacteria. To a large extent, it is left to the consumer to manage these hazards by making careful food choices, controlling consumption volumes and appropriate food handling. Other hazards are related to technological innovations that were designed to improve the supply and safety of foods, such as pesticides or additives. In developed countries, these hazards are subject to rigorous safety tests, regulation and control. Consumers can influence their exposure to technological hazards by choosing organic foods and reading labels on food packaging. In contrast, environmental chemicals represent a hazard that is altogether more difficult to control. These chemicals enter foods via unknown and uncontrolled routes. Their occurrence in foods can only be revealed through frequent and expensive controls.

Studies have shown that consumers may perceive food as hazardous where according to the experts, there is no objective risk. At the same time, consumers may ignore risk, even though its consequences on public health are observable. Traditionally, when communicating food hazards, scientific risk-assessors, policy makers and food producers used to focus on consumer education. This strategy was based on the assumption that if consumers' risk perceptions differed from the experts' assessment, the difference was based on consumers' relative lack of knowledge (Hansen, Holm, Frewer, Robinson, & Sandoe, 2003). In the meantime, research has shown that consumers' perception of food hazards is multidimensional and far away from the mathematic calculation used by experts to assess risk. Cognitive biases, attitudes, affects and trust influence consumers' hazard perceptions in a complex and interactive manner that depends on the hazard in question. Knowledge, the key factor in traditional risk communication, empirically plays an ambiguous role in consumers' risk perception.

5 Aims of the Present Research

Only when the psychological mechanisms behind consumers' risk perceptions are understood, can efficient risk communication be designed. Therefore, the first aim of the present research is to examine consumers' perceptions of food hazards in Switzerland. The currently ambiguous role of knowledge in food risk perception will be determined. Previously uninvestigated attitudes and beliefs (*determinants*) that are thought to be associated with food risk perception will be identified, and existing findings on attitudes and beliefs will be validated.

The second aim of the present work is to establish relationships between food hazard perceptions, knowledge about food hazards and behaviour. To know the contribution of psychological variables to consumers' nutrition behaviour may be of interest to all those dealing with the consequences of that behaviour, including health professionals, health authorities, policy makers, and the food industry.

The final aim of the present research is to make recommendations for food hazard communication which may have different purposes (Lundgren & McMakin, 2009; Visschers, 2007):

- Informing people about a hazard
- Encouraging them to make an informed decision as to whether to take action to prevent a risk or how to manage it
- To warn people in case of disasters and emergencies (crisis communication)
- To encourage joint problem solving and conflict resolution (consensus communication)
- To prevent panic and outrage

In a field that is characterized by heterogeneity, it is important that hazard communication is tailored to the hazard in question and the factors that shape its public perception. The hazards studied in the present work include overnutrition (also referred to as *calories*) and malnutrition, chemicals and microbiological hazards. Recent technologies such as the use of GM organisms or nanotechnology will not be part of the present research, nor will hazards related to food processing, such as irradiation or the formation of toxicants.

6 Overview of the Present Research

Six research studies (named Chapters II-VII) were conducted to answer various research questions regarding consumers' perceptions of food hazards and the behavioural consequences of these perceptions (Table 1.1). Data for all studies were collected through three large, written public surveys.

Chapter II: Phthalate Exposure Through Food and Consumers' Risk Perception of Chemicals in Food

This study dealt with environmental chemicals in food. Consumers' exposure to phthalates through diet was contrasted with their risk perceptions of chemicals in food and interest in eating a healthy and natural diet. Data were collected on consumers' habitual consumption of certain foods for which secondary data on phthalate concentrations were available. Results showed that consumers' risk perceptions and interest in a healthy and natural diet were not in line with their dietary exposure: consumers with a higher interest in a healthy and natural diet and higher risk perceptions of chemicals in food, through their food consumption were more exposed to some phthalates than consumers with fewer concerns. These findings illustrate that through food choice, consumers cannot influence their exposure to environmental chemicals such as phthalates. This study depicts the divergence between the subjective dimensions of exposure to chemicals through food and the objective reality, and it illustrates challenges and limits of food risk communication.

Chapter III: Attitudes Toward Chemicals are Associated with Preference for Natural Food

This study aimed to determine beliefs and attitudes held by consumers that influence their risk perception of chemicals in food and their interest in eating a natural diet. The risk perception of two types of chemicals was measured: contaminants (environmental and agricultural chemicals) and additives. Consumers' understanding of the dose-response principle, and their positive and negative attitudes towards chemicals were assessed as potential determinants of risk perception and natural diet interest. Structural equation modelling was used to shed light on the relationships between these variables. Results showed that positive attitudes toward chemicals lowered the risk perception of both types of chemicals in food. Correct understanding of the dose-response principle lowered risk perception of additives, but not of contaminants. Risk perception of additives and contaminants in food was positively related to interest in eating a natural diet, but the strength of this relationship varied according to the type of chemical. Men and women differed in their risk perception of chemicals in food. This study shows that to be effective, risk communication needs to be adapted to the type of chemical in question and to specific population groups.

Chapter IV: Development and Validation of a Short, Consumer-Oriented Nutrition Knowledge Questionnaire

Navigating away from chemicals in food, this study was embedded in the context of over- and malnutrition. Initially, the study intended to compare the role in dietary behaviour of knowledge versus beliefs about nutrition and health. Early in the study, it became clear that there were no existing instruments to assess nutrition knowledge that were suitable for the purpose of this study. Therefore, the focus of the study shifted to the development of a new nutrition knowledge questionnaire. Consumer interviews about nutrition and health were conducted to identify knowledge gaps to be included as items in the new questionnaire. Data from a public survey was used to establish the reliability and validity of the knowledge questionnaire. The questionnaire convinced with regard to psychometric and economical properties. Contrary to expectations, however, the relationships between the new questionnaire and dietary behaviour remained as moderate, as observed in other studies on nutrition knowledge and behaviour.

Chapter V: Consumers' Knowledge of Healthy Diets and its Correlation with Dietary Behaviour

The aims of this study were two-fold. The first aim was to extend research on the role of nutrition knowledge in dietary behaviour. From the item pool developed in Chapter IV, we created a knowledge scale specifically measuring procedural nutrition knowledge. The assessment of this type of knowledge stands in contrast to other studies on nutrition knowledge which focused on declarative nutrition knowledge. Results showed that correlations between procedural nutrition knowledge and behaviour were slightly higher than the correlations observed in other studies, confirming the expected stronger links of this type of knowledge to behaviour.

The second aim of this study was to discuss the implications for health communication of certain misconceptions held by consumers about nutrition and health. For example, many consumers interpreted the term “balanced diet” as a diet in which the different food groups are represented in equal amounts. This misconception is not in line with the food pyramid. Thus, health communication should enhance understanding of the food pyramid and raise awareness of the correct meaning of “balanced diet”.

Chapter VI: Consumers’ Perceptions of Food Safety- Implications for Hazard Communication

This study was intended to answer a range of open questions from the previous Chapters. The general aim was to assess predictors of risk perception of different food hazards and to measure associations of risk perception with hazard-related behaviour. This was a comparative study of different nutritional hazards. Perception of pesticides in food, additives, calories and bacteria was assessed. Predictors of perception included attitudes, beliefs, subjective and objective knowledge. The study was a mix of exploratory and hypothesis-driven research. Knowledge tests were developed regarding each hazard. Results showed that the selection and strength of significant determinants of risk perception depended on the specific hazard. The included predictors explained a satisfying part of the variance in consumers’ perception of additives and calories. In contrast, only a minor part of variance in the risk perception of pesticides and bacteria was explained by the predictors, indicating the influence of predictors not included in the present study. For each hazard, risk perception correlated with respective behaviour. The findings corroborate the need to adapt risk communication to the hazard in question, and the need for more research on the perception of microbiological and calorie-related food hazards.

Chapter VII: Consumers’ Knowledge and Perception of Food Additives

In the previous chapter, strong associations between the hypothesized predictors, risk perception of food additives, and additive-related behaviour were found. This study intended to investigate these relationships more systematically. A multiple regression analysis revealed significant influences of objective and subjective knowledge, trust in risk managers and communicators, perception of health consequences and negative attitudes toward chemicals on risk perception of food additives. Another focus of this study were the practical implications of consumers’ misconceptions about food additives. Altogether, the findings of this study highlighted the barriers to overcome for effective risk communication about food additives and the need for more consumer education about certain aspects of food additives, such as labelling rules on packaging.

Table 1.1 Research Overview: Studies Conducted (Chapters II-VII), Short Title, Main Research Questions, Methodology and Data Analysis Technique

Chapter	Title	Research question(s)	Methodology	Data analysis
II	Phthalate Study	Is there a correlation between consumers' perception of healthy and natural food and their exposure to phthalates through food?	Postal survey containing food frequency questionnaire (FFQ) and Likert scales	Cluster analysis Analysis of variance
III	Natural Food Preference	Are contaminants and additives in food perceived differently? Are risk perceptions of contaminants and additives related to natural diet interest? Are there gender differences in risk perceptions of contaminants and additives?	Postal survey containing Likert scales	Structural equation modelling
IV	Development of Nutrition Knowledge Questionnaire	Development of a new nutrition knowledge questionnaire Do experts score better than laypeople? Is the new questionnaire more closely related to nutrition behaviour than previous questionnaires?	Qualitative consumer interviews Public mail survey containing true/false knowledge questions and FFQ	Reliability analysis Validity analysis through bivariate correlations and t-tests Bivariate correlations
V	Procedural Nutrition Knowledge	Which misconceptions do consumers hold about healthy eating? Are these misconceptions related to nutrition behaviour? Do subgroups of the population differ in their knowledge about healthy eating?	Public mail survey containing true/false knowledge questions and FFQ	Reliability analysis Response frequencies Bivariate correlations T-tests
VI	Food Safety	What is the level of consumers' knowledge about additives, pesticides, bacteria and calories? What are the predictors of consumers' perception of these four hazards? Is risk perception of these four hazards related to behaviour?	Public mail survey containing true/false knowledge questions, Likert scales, assessments of self-reported behaviour	Reliability analyses Response frequencies Multiple regression analyses Bivariate correlations
VII	Knowledge and Perception of Food Additives	What are the implications of consumers' misconceptions about food additives? Which factors predict consumers' risk perceptions of food additives? Is risk perception related to behaviour?	Public mail survey containing true/false knowledge questions, Likert scales, assessments of self-reported behaviour	Reliability analysis Response frequencies Multiple regression analysis Bivariate correlations

References

Ahmed, F. E. (2001). Analyses of pesticides and their metabolites in foods and drinks. *Trends in Analytical Chemistry, 20*(11), 649-661.

Alhakami, A., & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis, 14*(6), 1085-1096.

Anderson, J. J. B. (2005). *Nutrition and health: An introduction*. Durham, NC: Carolina Academic Press.

Aronson, E., Wilson, T. D., & Akert, R. M. (2004). *Social psychology* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Barnett, J., & Breakwell, G. M. (2001). Risk perception and experience: Hazard personality profiles and individual differences. *Risk Analysis, 21*(1), 171-177.

Bundesamt für Gesundheit. (2006). Toxikologie von Pflanzenschutzmitteln. *Mitteilungen aus Lebensmitteluntersuchung und Hygiene, 94*, 261-274.

Bundesamt für Gesundheit. (2008). PCB und Dioxine in Lebensmitteln: Hintergrundinformationen. Retrieved from http://www.bag.admin.ch/themen/lebensmittel/04861/04911/index.html

Bundesamt für Gesundheit. (2010). Informationsschreiben Nr. 154: Teilharmonisierung der Höchstkonzentrationen für Pflanzenschutzmittel in oder auf Lebensmitteln mit der EU-Gesetzgebung. Retrieved from http://www.bag.admin.ch/themen/lebensmittel/04865/04894/index.html

DeFleur, M. L. (1966). *Theories of mass communication*. New York, NY: D McKay.

Dickson-Spillmann, M. (2008). *Consumers' mental models of the consequences of a healthy versus unhealthy nutrition*. Unpublished raw data.

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth, TX: Harcourt Brace Jovanovich College Publishers.

Europäische Kommission, & Generaldirektion Gesundheit und Verbraucher. (2008). Neue Vorschriften über Pestizidrückstände in Lebensmitteln: Merkblatt. Retrieved from http://ec.europa.eu/food/plant/protection/pesticides/explanation_pesticide_residues_de.pdf

European Centre for Disease Prevention and Control. (2010). *Annual epidemiological report on communicable diseases in Europe 2010*. Stockholm: Author. Retrieved from http://www.ecdc.europa.eu/en/publications/Publications/0910_SUR_Annual_Epidemiological_Report_on_Communicable_Diseases_in_Europe.pdf

European Commission. (2006). *Special Eurobarometer: Risk Issues* (238/ Wave 64.1). Retrieved from http://ec.europa.eu/public_opinion/archives/ebs/ebs_238_en.pdf

European Commission, & Health and Consumer Protection Directorate-General. (2008). Food Contamination: Fact Sheet. Retrieved from http://ec.europa.eu/food/food/chemicalsafety/contaminants/fs_contaminants_final_web_en.pdf

European Community. (2005). Regulation (EC) No 396/2005 of the European Parliament and Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC. *Official Journal of the European Union L 70, p. 1 of 16.3.2005*. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:070:0001:0016:en:PDF.

European Community. (2007). Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. *Official Journal of the European Union L 189, p. 1 of 20.7.2007.*

Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF.
European Community. (2008a). Commission Directive 2008/5/EC of 30 January 2008 concerning the compulsory indication on the labelling of certain foodstuffs of particulars other than those provided for in Directive 2000/13/EC of the European Parliament and of the Council. *Official Journal of the European Community L 27, p. 12 of 31.1.2008.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:027:0012:0016:EN:PDF.
European Community. (2008b). Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. *Official Journal of the European Community L 250, p. 1 of 18.9.2008.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:250:0001:0084:EN:PDF.
European Economic Community. (1988). Council Directive of 21 December 1988 on the approximation of the laws of the Member States concerning food additives authorized for use in foodstuffs intended for human consumption. *Official Journal of the European Community L 40, p. 27 of 11.2.1989.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav07_en.pdf.
European Economic Community. (1994a). European Parliament and Council Directive 94/35/EC of 30 June 1994 on sweeteners for use in foodstuffs. *Official Journal of the European Community L 237, p. 3 of 10. 9. 1994.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav10_en.pdf.
European Economic Community. (1994b). European Parliament and Council Directive 94/36/EC of 30 June 1994 on colours for use in foodstuffs. *Official Journal of the European Community L 237, p. 13 of 10.9.1994.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav08_en.pdf.
European Economic Community. (1995). European Parliament and Council Directive No 95/2/EC of 20 February 1995 on food additives other than colours and sweeteners. *Official Journal of the European Community L 61, p. 1 of 18. 3. 1995.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav11_en.pdf.
European Economic Community. (2000). Directive 2000/13/EC of the European Parliament and of the Council of 20 March 2000 on the approximation of the laws of the Member States relating to the labelling, presentation and advertising of foodstuffs. *Official Journal of the European Community L 109, p. 29 of 29.9.2000.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:109:0029:0042:EN:PDF.
European Food Safety Agency. (2010). Analysis of the baseline survey on the prevalence of Campylobacter in broiler batches and of Campylobacter and Salmonella on broiler carcasses in the EU 2008. *EFSA Journal, 8(03)*(1503), 1-99.
Fife-Schaw, C., & Rowe, G. (1996). Public perceptions of everyday food hazards: A psychometric study. *Risk Analysis, 16*(4), 487-500.
Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The affect heuristic in judgments of risks and benefits. *Journal of Behavioral Decision Making, 13*, 1-17.
Forschungsinstitut für biologischen Landbau. (2010). Betriebsmittelliste. Hilfsstoffliste für den biologischen Landbau in der Schweiz. Retrieved from https://www.fibl-shop.org/shop/pdf/1032-betriebsmittelliste.pdf
Frewer, L. J., Miles, S., & Marsh, R. (2002). The media and genetically modified foods: Evidence in support of social amplification of risk. *Risk Analysis, 22*(4), 701-711.

Frewer, L. J., Shepherd, R., & Sparks, P. (1994). The interrelationship between perceived knowledge, control and risk associated with a range of food-related hazards targeted at the individual, other people and society. *Journal of Food Safety, 14*(1), 19-40.

Geissler, C., & Powers, H. (2005). *Human nutrition* (11th ed.). London, England: Elsevier Churchill Livingstone.

Hansen, J., Holm, L., Frewer, L., Robinson, P., & Sandoe, P. (2003). Beyond the knowledge deficit: recent research into lay and expert attitudes to food risks. *Appetite, 41*(2), 111-121.

House, L., Lusk, J., Jaeger, S., Traill, W. B., Moore, M., Valli, C., . . . Yee, W. M. S. (2004). Objective and subjective knowledge: Impacts on consumer demand for genetically modified foods in the United States and the European Union. *AgBioForum, 7*(3), 113-123.

Huotilainen, A., & Tuorila, H. (2005). Social representation of new foods has a stable structure based on suspicion and trust. *Food Quality and Preference, 16*(7), 565-572.

Johansson, L., Thelle, D. S., Solvoll, K., Bjorneboe, G. E. A., & Drevon, C. A. (1999). Healthy dietary habits in relation to social determinants and lifestyle factors. *British Journal of Nutrition, 81*(3), 211-220.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., . . . Ratick, S. (1988). The social amplification of risk - a conceptual framework. *Risk Analysis, 8*(2), 177-187.

Kates, R. W., & Kasperson, J. X. (1983). Comparative risk analysis of technological hazards. *Proceedings of the National Academy of Sciences, 80*, 7027-7038.

Kirk, S. F. L., Greenwood, D., Cade, J. E., & Pearman, A. D. (2002). Public perception of a range of potential food risks in the United Kingdom. *Appetite, 38*(3), 189-197.

Klohe-Lehman, D. M., Freeland-Graves, J., Anderson, E. R., McDowell, T., Clarke, K. K., Hanss-Nuss, H., . . . Milani, T. J. (2006). Nutrition knowledge is associated with greater weight loss in obese and overweight low-income mothers. *Journal of the American Dietetic Association, 106*(1), 65-75.

Knowles, T., Moody, R., & McEachern, M. G. (2007). European food scares and their impact on EU food policy. *British Food Journal, 109*(1), 43-67.

Lundgren, R. E., & McMakin, A. H. (2009). *Risk communication: A handbook for communicating environmental, safety, and health risks*. Hoboken, NJ: John Wiley & Sons.

Magkos, F., Arvaniti, F., & Zampelas, A. (2003). Putting the safety of organic food into perspective. *Nutrition Research Reviews, 16*(2), 211-222.

Manary, M. J., & Solomons, N. W. (2004). Public health aspects of undernutrition. In M. J. Gibney (Ed.), *Public health nutrition* (pp. 178-191). Oxford, England: Blackwell Science.

Miles, S., Braxton, D. S., & Frewer, L. J. (1999). Public perceptions about microbiological hazards in food. *British Food Journal, 101*(10), 744-762.

Montville, T. J., & Matthews, K. R. (2008). *Food microbiology: An introduction* (2nd ed.). Washington, DC: ASM Press.

Nishida, C., & Mucavele, P. (2004-2005). Overweight and obesity: a new nutrition emergency? *SCN News, 29*, 5-12.

Parry, S. M., Miles, S., Tridente, A., Palmer, S. R., & South and East Wales Infectious Disease Group. (2004). Differences in perception of risk between people who have and have not experienced Salmonella food poisoning. *Risk Analysis, 24*(1), 289-299.

Pidgeon, N. (1992). Risk perception. In N. Pidgeon, C. Hood, D. Jones, B. Turner & R. Gibson (Eds.), *Risk analysis, perception and management: Report of a Royal Society Study Group* (pp. 89-134). London, England: The Royal Society.

Pollard, J., Kirk, S. F. L., & Cade, J. E. (2002). Factors affecting food choice in relation to fruit and vegetable intake: a review. *Nutrition Research Reviews, 15*(2), 373-387.

Saba, A., & Messina, F. (2003). Attitudes towards organic foods and risk/benefit perception associated with pesticides. *Food Quality and Preference, 14*(8), 637-645.

Schneider, H., & Schmid, A. (2004). *Die Kosten der Adipositas in der Schweiz: Schlussbericht*. Bern, Switzerland: Bundesamt für Gesundheit.

Seidell, J. C., & Visscher, T. L. S. (2004). Public health aspects of overnutrition. In M. J. Gibney (Ed.), *Public health nutrition* (pp. 167-177). Oxford, England: Blackwell Science.

Sharpe, R. M., & Irvine, D. S. (2004). How strong is the evidence of a link between environmental chemicals and adverse effects on human reproductive health? *British Medical Journal, 328*(7437), 447-451.

Shepherd, R., & Towler, G. (1992). Nutrition knowledge, attitudes and fat intake - application of the theory of reasoned action. *Journal of Human Nutrition and Dietetics, 5*(6), 387-397.

Shibamoto, T., & Bjeldanes, L. (2009). *Introduction to food toxicology*. Oxford, England: Elsevier.

Siegrist, M. (1998). Belief in gene technology: The influence of environmental attitudes and gender. *Personality and Individual Differences, 24*(6), 861-866.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*(2), 195-203.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science & Technology, 19*(11), 603-608.

Siegrist, M., & Cvetkovich, G. (2000). Perception of hazards: The role of social trust and knowledge. *Risk Analysis, 20*(5), 713-719.

Siegrist, M., Keller, C., & Kiers, H. A. L. (2006). Lay people's perception of food hazards: Comparing aggregated data and individual data. *Appetite, 47*(3), 324-332.

Slovic, P. (1987). Perception of risk. *Science, 236*(4799), 280-285.

Sparks, P., & Shepherd, R. (1994). Public perceptions of the potential hazards associated with food-production and food-consumption - an empirical study. *Risk Analysis, 14*(5), 799-806.

Sumner, S. S., & Eifert, J. D. (2002). Risks and benefits of food additives. In A. L. Branen, P. M. Davidson, S. Salminen & J. H. Thorgate III (Eds.), *Food Additives* (2nd ed.). New York, NY: Marcel Dekker.

Tversky, A., & Kahneman, D. (1973). Availability - Heuristic for judging frequency and probability. *Cognitive Psychology, 5*(2), 207-232.

Visschers, V. H. M. (2007). *Gut feeling versus common sense: The role of associative and cognitive processes in risk perception and communication.* PhD Thesis, University of Maastricht, Maastricht, Netherlands.

Wansink, B. (2004). Environmental factors that increase the food intake and consumption volume of unknowing consumers. *Annual Review of Nutrition, 24*, 455-479.

Wardle, J., Parmenter, K., & Waller, J. (2000). Nutrition knowledge and food intake. *Appetite, 34*(3), 269-275.

Weinstein, N. D. (1980). Unrealistic optimism about future life events. *Journal of Personality and Social Psychology, 39*(5), 806-820.

World Health Organization. (2003). *Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation* (Technical report series, No. 916). Geneva, Switzerland: Author.

Chapter II

Phthalate Exposure Through Food and Consumers’ Risk Perception of Chemicals in Food

Abstract

Phthalates have been detected in various types of retail food. Consumer exposure to phthalates is common. Consumers are concerned about chemicals in food. Our aim was to investigate the relationships between consumer exposure to phthalates through food, consumer interest in a natural and healthy diet, risk perception of food chemicals and consumer diet patterns. We collected data through a mail survey in the adult Swiss-German population (*N* = 1,200). We modelled exposure to DEHP, DBP, BBP and DEP based on a food frequency questionnaire and phthalate concentrations reported from food surveys. Using rating scales, we assessed risk perceptions of chemicals in food and interest in a natural and healthy diet. Higher risk perceptions and higher natural and healthy diet interest were associated with higher daily doses of DEHP, BBP and DEP. No health risk from phthalates in food was identified for the vast majority of the population. Four consumer diet clusters were discerned, with differences in phthalate exposure, risk perceptions, and interest in a natural and healthy diet. This study shows that even those consumers who express strong interest in natural food and low acceptance of food chemicals, and who try to make respective food choices, are exposed to contaminants such as phthalates.

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1 Introduction

Phthalates are a group of organic compounds that are used to soften polyvinylchloride (PVC) and other plastics. They are found in a wide range of consumer products, and they are omnipresent in the residential space and in the environment (Bornehag et al., 2005; Peijnenburg & Struijs, 2006; Rudel, Camann, Spengler, Korn, & Brody, 2003). Biomonitoring studies have shown the ubiquitous exposure of consumers to phthalates in all age groups of the general population (Koch et al., 2007; Koch, Drexler, & Angerer, 2003; Silva et al., 2004; Wittassek et al., 2007). Food has been shown to be an important source of exposure for several phthalic diesters (Fromme et al., 2007; Wormuth, Scheringer, Vollenweider, & Hungerbuhler, 2006).

The first aim of our study was to investigate consumer exposure to phthalates in food. In view of the fact that many consumers are concerned about health risks arising from chemicals in food (European Commission, 2006), our second aim was to examine the relationships between phthalate exposure, consumers' risk perceptions of chemicals in food and interest in eating a natural and healthy diet.

1.1 Phthalates in Food

The most likely explanation of the occurrence of phthalates in retail food is the frequent use or unintended presence of phthalates in various food contact materials during processing, storing and transport (Ministry of Agriculture Fishery and Food, 1996). These food contact materials range from packaging, conveyor belts and gloves to hoses (Heudorf, Mersch-Sundermann, & Angerer, 2007). This is even so after the European Union strictly restricted phthalate use in food contact materials (European Commission, 2004). Phthalates are not chemically bound to the plastics and therefore may migrate from the materials into the foodstuff (Castle, Mercer, Startin, & Gilbert, 1988).

1.2 Health Effects of Phthalates

Toxicological studies have shown considerable adverse health effects of phthalates and their metabolites. Several phthalic diesters, some of which are frequently present in food, are associated with an impairment of the development of the male reproductive system in rodents (Gray et al., 2000; Mylchreest, Cattley, & Foster, 1998) and possibly in humans (Swan et al., 2005). These outcomes are thought to be due to the endocrine disruptive action of phthalates during the phase of sexual differentiation in the foetus (Hauser & Calafat, 2005). Shortened duration of pregnancy leading to preterm birth (Latini et al., 2003) has also been associated with phthalate exposure. For these reasons, women of reproductive age may be considered an especially vulnerable segment of the population with regard to phthalate exposure. Further effects observed in connection with phthalate exposure include premature breast development in young girls (Colon, Caro, Bourdony, & Rosario, 2000) and reduced semen production and quality in adult men (Hauser & Calafat, 2005). Although evidence in humans is still limited, phthalates are a concern to health authorities. The European Food Safety Agency proposed tolerable daily intake values (TDIs) (European Food Safety Agency, 2005a, 2005b, 2005c).

1.3 Consumer Exposure to Phthalates in Food

Quantitative studies of consumer exposure to phthalates through food are scarce, although their role in comprehensive risk assessment has been emphasized (Fromme, et al., 2007). Previous studies have reported dietary phthalate intake ranges based on duplicate food samples or based on aggregated population data (Kuchen et al., 1999; Ministry of Agriculture Fishery and Food, 1996; Petersen & Breindahl, 2000). These studies have found widespread contamination of foods with various phthalates; but potential exposure resulting from the consumption of these foods did not exceed the respective TDIs. Nevertheless, it was pointed out that phthalates in food should receive further attention (Kuchen, et al., 1999).

An exposure modelling study based on aggregated survey data by Wormuth et al. (2006) suggested that food was the most important source of exposure for several phthalates, accounting for up to 98% of total exposure. A recent study using biomonitoring, and measuring phthalate concentrations in duplicate diet samples, indicated that food was the major source of exposure to *di(2-ethylhexyl) phthalate* (DEHP) in a German adult population (Fromme, et al., 2007). While these studies supported the view that food consumption is an important pathway of exposure to phthalates for consumers, it is not known whether some subgroups of the adult population are more exposed to phthalates than others. A previous exposure modelling study by Wormuth et al. (2006) investigated exposure based on age and gender. In that study, average food consumption data taken from international surveys rather than effective consumption data from a specific population was used; thus, the study provided a rather theoretical picture of dietary phthalate exposure in these subgroups.

1.4 Consumer Concerns about Chemicals in Food

Health concerns play an important role in European consumers' food choices, as well as taste, quality, freshness, price and family preferences (Brug, Debie, Vanassema, & Weijts, 1995; Lennernäs et al., 1997; Pollard, Kirk, & Cade, 2002). Health concerns influence risk perceptions of ingredients and of food technologies, and modify dietary and nutritional behaviours (Frewer & Miles, 2001).

Food chemicals are an object of many health concerns. "Food chemicals" ranked second (behind "food poisoning") in European consumers' associations with possible problems and risks related to food (European Commission, 2006). Animal hormones, antibiotics, pesticides and food additives ranked among the top ten public concerns about food in Germany and in the UK (Bundesforschungsinstitut für Ernährung und Lebensmittel, 2008; Miles et al., 2004).

The dimensions underlying consumer perception of various chemicals in food have been investigated. Hazards involving unwanted by-products of production processes, such as pesticide residues, hormone residues and veterinary drug residues were perceived as severe, unknown and unobservable hazards (Siegrist, Keller, & Kiers, 2005, 2006; Sparks & Shepherd, 1994). Environmental contamination of food was seen as highly severe by consumers. This was in contrast to food hazards such as over or under-consumption of nutrients, which were perceived as low-severity and well-known hazards (Sparks & Shepherd, 1994). "Substances migrating from plastics" were associated in consumers' minds with the terms "poisonous" and "harmful", and consumer attitudes toward these chemicals were very unfavourable (Raats & Shepherd, 1996).

One strategy consumers use to avoid food chemicals is buying organic produce. Consumers equate organic foods to foods without synthetic chemicals, and organic foods are perceived to be more natural and healthier than non-organic foods (von Alvensleben, 2001). Buying organic food is an efficient strategy to reduce exposure to synthetic chemicals, such as additives and agricultural chemicals, as organic food production is aimed at eliminating these chemicals from food products (European Economic Community, 2006). Due to the multitude of phthalate sources and the difficulty in controlling these sources (Ministry of Agriculture Fishery and Food, 1996), however, conventionally and organically produced food products may be similarly contaminated with phthalates.

1.5 Aims of our Study

In this paper, we pursued two aims: firstly, to model consumer exposure to phthalates through food. By using a food frequency questionnaire in the context of a survey, we gathered data on effective food consumption. Secondly, we aimed to investigate the relationships between consumer interest in a natural and healthy diet, risk perceptions of synthetic food chemicals, and phthalate exposure through food. We hypothesized that if we could identify such relationships, they would be explained by consumers' dietary patterns. To our knowledge, this is the first interdisciplinary study to relate psychological dimensions to the physical reality of contaminant exposure through food.

2 Materials and Methods

2.1 Participants

A mail survey was conducted between January and March 2008. Three thousand randomly selected households in the German-speaking part of Switzerland were contacted. The household member over 18 years of age whose birthday was next was asked to fill in the questionnaire. Two reminders were sent out to non-responders; the second reminder contained another copy of the questionnaire. A response rate of 41.1% (N = 1,234) was achieved.

Of 1,186 participants who reported their gender, 49.5% (n = 587) were female and 50.5% (n = 599) were male. The mean age was 52.8 (15.8) years. Compared to Swiss census data (Bundesamt für Statistik, 2009), the mean age in the present sample was slightly higher. No special dietary habits were reported by 89.2% (n = 1,045) of the participants, while 4.4% (n = 51) were vegetarians, 0.4% (n = 5) vegans, and 6.0% (n = 71) reported pursuing a special diet due to health reasons such as diabetes or allergies.

2.2 Materials

2.2.1 Food Frequency Assessment

For quantification of phthalate exposure and identification of diet patterns, the questionnaire contained a food frequency assessment including 29 food items (for a full list, see Table 2.3). The food items were chosen on the basis of food quality studies that reported phthalate concentrations (Wormuth, et al., 2006).

For nine food items (e.g. ready soup, salty snacks, fresh vegetables), a standard portion size of two decilitres was indicated. For the other items (e.g. butter, supplements, banana), individual portion sizes were given. Respondents were asked to indicate their consumption frequency using the seven categories *twice or more a day* (score 1), *once a day* (2), *5-6 a week* (3), *2-4 a week* (4), *1 a week* (5), *1-3 a month* (6) and *rarer* (7). To standardize the unit of measurement, these categories were transformed into consumption frequency per day as follows: 2, 1, 0.79, 0.43, 0.14, 0.06, 0.

One hundred and forty nine participants showed missing food frequency values. Data imputation was undertaken in participants with up to two missing values. Visual inspection of correlation tables between food frequencies suggested data imputation via regression analysis to be inappropriate, as most observed correlations were low. Thus, we decided to perform mean imputation on the food frequency scores. Imputed means were rounded for computation of phthalate exposure but not for the cluster analysis.

2.2.2 Exposure Modelling

The most frequently detected phthalates in food are DEHP and *dibutyl phthalate* (DBP), followed by *benzyl butyl phthalate* (BBP) and *diethyl phthalate* (DEP). Data on phthalate concentrations in food were taken from food surveys (Wormuth, et al., 2006), including a Swiss study in which food from different retail shops was purchased, mixed in the laboratory and analysed as homogenised samples (Kuchen, et al., 1999). With the intention of gaining a long-term perspective on consumer phthalate exposure, we assumed intermediate phthalate concentrations in foods (as opposed to high or low reported concentrations). Therefore, the median of the distribution of reported phthalate concentrations for every food item was calculated. Phthalate exposure and resulting internal doses (E_{food}) were calculated based on this median (c_{food}), the food consumption frequency (q_{food}) per day, gastrointestinal uptake efficiency (r_{GI}) and body weight (bw) as follows:

$$E_{food} = \frac{\sum_{i=1}^{n} \left(c_{food} \cdot q_{food} \right)}{bw} \cdot r_{GI}$$

More details about the calculation procedure are reported in Wormuth et al.(2006) Calculated doses were compared to the TDI (European Food Safety Agency, 2005a, 2005b, 2005c; US Environmental Protection Agency, 1993) for the respective phthalate.

2.2.3 Natural Product Interest and General Health Interest

The questionnaire included the natural product interest and the general health interest scales from the Health and Taste Attitude Questionnaires (Roininen, Lahteenmaki, & Tuorila, 1999). The Natural Product Interest scale measures consumer interest in consuming unprocessed foods, organic foods and foods that do not contain synthetic chemicals. The General Health Interest scale assesses consumer interest in eating healthily, for example a balanced diet or a diet high in vitamins and minerals. Reliability analysis included calculation of Cronbach's α, which is a measure of the internal consistency of a scale (Field, 2005). The higher the value, the higher the consistency of the scale; values higher than 0.7 are regarded as suitable. The Natural Product Interest scale (6 items) showed a Cronbach's α of .76 and the Health Interest scale (7 items[1]) of α = .84.

Individual scale means were computed. With respect to natural product interest, a scale mean was computed for participants with no more than two missing values. With regard to general health interest, a scale mean was calculated if no more than one value was missing. These values were arbitrarily chosen, so that 98.5% of the sample had non-missing values.

2.2.4 Risk Perception of Chemicals in Food

Participants were asked to rate the risk perceived from eight chemicals present in food. The risk ratings of chemicals were introduced as follows: "The following chemicals may occur in food. How high do you think your personal health risk is from these chemicals?" Risk perception for every chemical was indicated on a scale from 1 (*no risk*) to 6 (*high risk*), with

[1] Item number 8 of the General Health Interest scale by Roininen et al. was not used because it was deemed that the general population, especially younger respondents, might not be familiar enough with the health implications of enhanced blood cholesterol levels to respond to this item.

the option of responding "don't know this chemical." The chemicals belonged to two categories: additives (i.e. intended inclusion in food to enhance quality: preservatives, artificial colourings, artificial flavourings) and contaminants (i.e. non-intended inclusion in food; often side-products of processing: pesticides, phthalates, transfats, antibiotics, dioxins). For additives, means were computed only for respondents who had rated all three chemicals. For contaminants, means were computed for respondents with risk ratings for at least four items. Reliability analysis yielded a Cronbach's α of .77 for the contaminants scale (3 items) and α = .83 for the additives scale (5 items).

2.3 Statistical Analysis

We used Pearson's correlations to examine the relationship between consumer interest in natural and healthy food, risk perceptions of chemicals in food, and phthalate exposure.

We performed cluster analysis on food consumption frequency data to identify consumer groups with highest within-group similarity in diet patterns and maximal dissimilarity between groups. As our sample was large ($N > 1{,}000$), we used *k-means* cluster analysis. Two multivariate analyses of variance (MANOVAs) were conducted to investigate main effects of the independent variable cluster membership on exposure to the four phthalates and on the four psychological variables (natural product interest, general health interest, risk perception of additives and risk perception of contaminants). Post-hoc group comparisons were made using Tukey's HSD test. We quantified associations between categorical variables (e.g. cluster membership and gender) via chi-square tests. The level of statistical significance was set to 0.01 for all analyses.

3 Results

3.1 Consumer Phthalate Exposure Through Food

Modelled phthalate exposure of the total sample through food is given in Table 2.1.

Median exposures did not exceed 4% of the TDI for any phthalate. The highest approximation of an individual to the TDI was observed with DBP (75% of the TDI). Inspection of the DBP exposure histogram showed that if this individual was removed from the dataset, the next lower exposure would be 5.1 µg per kg body weight per day (51% of the TDI). The 99th percentile of DBP exposure was at 3.83µg/kg body weight/day, i.e. 38% of the TDI, the 95th percentile was at 1.17µg/kg body weight/day (12% of the TDI). Thus, even for DBP, to which few individuals were highly exposed, the vast majority of consumers were far from reaching the TDI.

Table 2.1: TDIs and Descriptives of Modelled Daily doses of Four Phthalates Through Diet (μg/kg Body-Weight/Day)

Phthalate	TDI	*Mdn*	*Mdn* % TDI[a]	*IQR*	*Min*	*Max*	*Max* % TDI[b]
DEHP	50	1.90	3.80	1.16	0.36	8.21	16.42
DBP	10	0.39	3.90	0.34	0.03	7.48	74.80
BBP	500	0.14	0.03	0.19	0.00	0.63	0.13
DEP	800	0.02	0.00	0.01	0.00	0.07	0.01

Note. TDI = Tolerable daily intake (European Food Safety Agency, 2005a, 2005b, 2005c; US Environmental Protection Agency, 1993)
N = 1183 due to 17 cases who did not indicate their weight
[a] The percentage of the TDI represented by the median exposure value
[b] The percentage of the TDI represented by the maximum exposure value

3.2 Relationships Between Psychological Variables and Phthalate Exposure

Table 2.2 shows correlations between psychological variables and phthalate exposure. There were significant correlations between exposure to BBP and all psychological variables (*p*s < .001). Higher risk perception of additives and contaminants, higher natural product and general health interest were related to higher BBP exposure. Further, higher natural product and general health interest were associated with higher DEHP and DEP exposure (*p*s < .001). Given these relationships, we investigated whether consumer diet clusters could be identified that showed between-cluster differences in phthalate exposure and in psychological variables.

Table 2.2: Pearson's Correlations Between Psychological Variables and Food-Related Exposure to Phthalates

				r	
Risk perceptions and diet interests	*N*	DEHP	DBP	BBP	DEP
Risk perception contaminants	1062	-.01	.02	.15*	.02
Risk perception additives	1143	.01	.05	.13*	.02
Natural product interest	1167	.16*	.00	.25*	.20*
General health interest	1169	.10*	.01	.28*	.24*

Note. * $p \leq .001$
N varies due to "don't know this chemical" answers, missing data on body weight and in rating scales

3.3 Diet Clusters

A review of consumer food pattern literature suggested a range of between two and six food patterns (McNaughton, Ball, Mishra, & Crawford, 2008; Schulze & Hoffmann, 2006; Waijers et al., 2006). We tested solutions with two to five clusters. ANOVA showed non-significant group differences in twelve food items with the two and three cluster solutions. The five cluster solution showed low substantial interpretability. The four cluster solution offered high interpretability, and clusters differed significantly on all except six food items. Of those items significantly contributing to the cluster solution, the lowest *F*-value was observed for ready soups, $F(3,1196) = 3.798$, $p = .010$. Table 2.3 shows the mean daily consumption of the foods per cluster. There were two clusters which showed diet patterns characterized by high consumption of fruit and vegetables, nuts, seeds and whole wheat bread. The most marked difference between the two clusters was the consumption of vitamin and mineral supplements. The cluster with high consumption of supplements was labelled Healthy and

Supplements (n = 290), while the other cluster was labelled Healthy and Natural (n = 306). The Healthy and Natural cluster showed lowest consumption of ready-made foods such as pizza, processed meats and salty snacks. A third cluster showed lowest consumption of a range of foods, particularly dairy (cream, cheese, and yoghurt), fruit and vegetables, whole wheat and grains. This cluster did not show particularly high consumption of any foods. As it was not so much characterized by high consumption of unhealthy foods but rather by not consuming healthy foods, we called this cluster Health-Passive (n = 321). The last cluster showed highest consumption of most foods, particularly dairy products, meats, ready-made foods and sweets. There were no foods that were least consumed by this group. Thus, we labelled this cluster Sweet, Fatty and Ready-Meal (n = 283).

Table 2.3: Mean consumption frequencies of 29 foods per day, according to diet cluster

	Cluster consumption frequency							
	Healthy and Supplements (n = 290)		Healthy and Natural (n = 306)		Health-Passive (n = 321)		Fat, Sweet and Ready-Meal (n = 283)	
Food items	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Supplements (tablets)	1.04	0.38	0.04	0.10	0.16	0.33	0.06	0.14
Cereals (2dl)	0.53	0.46	0.46	0.44	0.14	0.24	0.47	0.43
Nuts, grains (handfuls)	0.41	0.45	0.35	0.41	0.07	0.15	0.24	0.35
Fresh fruit (pieces)	1.15	0.57	1.21	0.62	0.49	0.50	0.97	0.54
Whole wheat bread (slices)	1.01	0.65	1.13	0.66	0.26	0.37	0.75	0.59
Fresh vegetables (2dl)	1.07	0.53	1.12	0.56	0.58	0.40	1.00	0.54
Fish (2dl)	0.14	0.13	0.14	0.15	0.11	0.17	0.13	0.14
Ready meals (plates)	0.03	0.13	0.01	0.05	0.05	0.13	0.05	0.11
Cheese (slices)	0.75	0.50	0.68	0.51	0.51	0.43	0.89	0.52
Butter (table spoons)	0.65	0.54	0.62	0.53	0.51	0.45	0.83	0.55
Yoghurt (cups)	0.61	0.47	0.57	0.46	0.28	0.32	0.78	0.48
Sweets (pieces)	0.48	0.45	0.34	0.38	0.33	0.40	0.69	0.50
Red meat (2dl)	0.34	0.28	0.30	0.25	0.47	0.33	0.53	0.35
Banana (pieces)	0.40	0.41	0.35	0.44	0.17	0.26	0.47	0.43
Processed meats (slices)	0.28	0.33	0.13	0.17	0.28	0.28	0.45	0.39
Biscuits (2dl)	0.28	0.31	0.16	0.22	0.17	0.24	0.39	0.33
White bread (slices)	0.23	0.31	0.11	0.16	0.37	0.48	0.38	0.41
Margarine (table spoons)	0.32	0.47	0.13	0.29	0.22	0.35	0.37	0.51
Poultry (2dl)	0.22	0.19	0.18	0.19	0.22	0.23	0.26	0.24
Cream (cups)	0.14	0.17	0.12	0.16	0.10	0.14	0.24	0.29
Salty snacks (2dl)	0.09	0.16	0.05	0.11	0.11	0.16	0.16	0.25
Preserved vegetables (handfuls)	0.11	0.15	0.07	0.10	0.09	0.14	0.14	0.17
Ready soup (2dl)	0.09	0.21	0.03	0.10	0.06	0.16	0.11	0.18

	Cluster consumption frequency							
	Healthy and Supplements (n = 290)		Healthy and Natural (n = 306)		Health-Passive (n = 321)		Fat, Sweet and Ready-Meal (n = 283)	
Food items	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Ready sauce (2dl)	0.06	0.12	0.03	0.06	0.09	0.14	0.11	0.20
Cake (slices)	0.05	0.13	0.02	0.07	0.05	0.13	0.10	0.21
Preserved fruit (handfuls)	0.08	0.19	0.04	0.10	0.05	0.11	0.10	0.16
Asian sauces (table spoons)	0.05	0.11	0.03	0.13	0.03	0.08	0.08	0.17
Ready pizza frozen	0.03	0.13	0.01	0.03	0.03	0.07	0.05	0.11
Ready pizza chilled	0.01	0.04	0.01	0.02	0.02	0.07	0.04	0.11

Note. N = 1200
Foods printed in bold were eaten by members of the respective diet cluster more often than by members of the other clusters
Portion sizes are as given in the food frequency questionnaire.
Non-significant contribution (p > .01) of the following food items to the cluster solution was observed with poultry, frozen pizzas, ready-meals, preserved fruits and vegetables, and Asian sauces.

The association between cluster and gender was significant, $\chi^2(3) = 84.32$, p < .01. Men were over-represented in the Health-Passive (67.8%, n = 215) and the Fat, Sweet and Ready-Meal (57.9%, n = 161) diet clusters, and women were over-represented in the Healthy and Natural (64.8%, n = 197) and Healthy and Supplements (59.6%, n = 171) diet clusters. *ANOVA* showed a significant effect of cluster on age, $F(3,1181) = 6.64$, p < .01. Post-hoc tests revealed that the Healthy and Supplements (M = 55.3, SD = 15.0) and Healthy and Natural clusters (M = 54.4, SD = 15.5) did not differ with regard to age, but they were both older than the Health-Passive (M = 50.7, SD = 16.4) and the Fat, Sweet and Ready-Meal clusters (M = 50.9, SD = 15.9). The latter two clusters did not differ in age. The association between special diet habits (vegetarian, vegan, health reasons) and cluster was not significant ($\chi^2(9) = 21.13$, p > .01).

3.4 Psychological Variables and Cluster Membership

Table 2.4 shows cluster means for the psychological variables. MANOVA yielded a main effect of cluster on natural product interest, $F(3,1045) = 48.10$, p < .01. Post-hoc comparisons revealed significant differences between all cluster pairs (ps < .01) except the Healthy and Natural and the Healthy and Supplements clusters (p = .05), which showed highest values. The Health-Passive cluster showed the lowest natural product interest. A main effect of cluster was observed on general health interest, $F(3,1045) = 73.34$, p < .01. The pattern was similar to natural product interest. No difference was observed between the Healthy and Supplements and Healthy and Natural clusters (p = .80). All other cluster comparisons were significant (ps < .01), with the Health-Passive cluster showing lowest general health interest.

MANOVA revealed a main effect of cluster on risk perception of contaminants in food, $F(3,1045) = 16.24$, p < .01. The two health-oriented clusters showed similar risk perception (p = .80), which was higher than in the two other groups (ps < .01). The two less health-oriented groups did not differ in risk perception of contaminants (p = .63). A main effect of cluster on risk perception of food additives was observed, $F(3,1045) = 15.23$, p < .01. The

Healthy and Natural cluster showed higher risk perception of additives than the other three clusters (*p*s < .01), which did not differ from one another (*p*s > .01).

Table 2.4: Risk Perceptions and Attitudes Toward Chemicals in Food, According to Cluster

	Cluster							
	Healthy and Supplements		Healthy and Natural		Health-Passive		Fat, Sweet and Ready-Meal	
Risk perceptions and diet interests	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Natural product interest	4.21	1.01	4.44	0.99	3.48	0.98	3.84	0.96
n	287		303		316		278	
General health interest	4.81	0.78	4.87	0.73	3.93	1.06	4.24	0.91
n	288		303		317		278	
Risk perception contaminants	4.69	0.96	4.76	0.91	4.28	0.95	4.38	1.00
n	257		284		270		264	
Risk perception additives	3.13	1.14	3.51	1.18	2.97	1.13	2.91	1.05
n	283		297		301		277	

Note. The higher the score, the higher the risk perceptions, natural product and general health interest.
The minimum score is 1, the maximum score is 6.
N varies due to "don't know this chemical" answers and missing data in rating scales

3.5 Exposure to Phthalates and Cluster Membership

Table 2.5 shows phthalate exposure according to cluster. MANOVA revealed a main effect of cluster on dose for all four phthalates (DEHP: $F(3,1179) = 116.51$, DBP: $F(3,1179) = 22.39$, BBP: $F(3,1179) = 139.26$, DEP: $F(3,1179) = 134.91$), *p*s < .01). For DEHP, Tukey's HSD showed that all cluster differences were significant (*p*s < .01). Highest exposure was observed in the Fat, Sweet and Ready-Meal cluster, the two health-oriented clusters ranked second and third. For DBP, the Fat, Sweet and Ready-Meal cluster was more exposed than the other three clusters (*p*s < .01). The Healthy and Supplements cluster was more exposed than the Health-Passive cluster ($p < .01$). The Healthy and Supplements cluster compared to the Healthy and Natural cluster, and the Healthy and Natural compared to the Health-Passive cluster did not differ from each other (*p*s > .01). The Health-Passive cluster was least exposed. For BBP, all clusters differed significantly (*p*s < .01) except the Healthy and Supplements and Healthy and Natural clusters ($p = .20$). The Healthy and Natural cluster, which was characterized by highest natural product interest and highest risk perception of additives, showed highest exposure, and the Health-Passive cluster was least exposed. Regarding DEP, all clusters showed low exposure. There were no differences between the Healthy and Supplements, the Healthy and Natural and the Fat, Sweet and Ready-Meal clusters, while the Health-Passive cluster was significantly less exposed than the other three clusters (*p*s < .01). Thus, the cluster showing the lowest health interest was least exposed to DEP, while the two strongly health-interested groups were as exposed as the Fat, Sweet and Ready-Meal cluster.

Table 2.5: Median Modeled Doses of Four Phthalates Through Diet (µg/kg Body-Weight/Day), According to Diet Cluster

	Cluster			
	Healthy and Supplements (*n* = 287)	Healthy and Natural (*n* = 304)	Health-Passive (*n* = 317)	Fat, Sweet and Ready-Meal (*n* = 275)
Phthalate	*Mdn (IQR)*	*Mdn (IQR)*	*Mdn (IQR)*	*Mdn (IQR)*
DEHP	2.144 (1.154)	1.907 (0.964)	1.295 (0.802)	2.398 (1.349)
DBP	0.434 (0.312)	0.360 (0.276)	0.244 (0.298)	0.516 (0.410)
BBP	0.191 (0.187)	0.208 (0.208)	0.032 (0.066)	0.143 (0.139)
DEP	0.028 (0.012)	0.025 (0.014)	0.015 (0.009)	0.028 (0.016)

Note. *N* = 1183 due to 17 cases who did not indicate their weight

4 Discussion

Our study represents a quantification of the daily dose of phthalates ingested via food by Swiss consumers. This study is a continuation of the work of Wormuth et al. (2006). By using consumption data from a specific population, our dose estimates are more accurate and allow for analysis of subgroup differences in food-related phthalate exposure.

Our study is interdisciplinary and adds aspects of risk perception to exposure assessment. We showed that subjective dimensions of chemical exposure, such as risk perceptions of chemicals in food and interest in natural food products, were related to phthalate exposure in a manner that seemed paradoxical: consumers with higher risk perceptions of food chemicals and higher interest in natural products were more exposed to some phthalates.

4.1 Exposure to Phthalates Through Food

Our study quantifies the internal dose of phthalates received via food by consumers. We can compare our external dose estimates[2] to previous food exposure studies (Fromme, et al., 2007; Ministry of Agriculture Fishery and Food, 1996). Our results are in the lower region of the medians of other studies (DBP) or below the median range (DEHP, DEP) (Fromme, et al., 2007). BBP exposure according to our estimate is higher than exposure estimated by the MAFF (Ministry of Agriculture Fishery and Food, 1996), but in that study a smaller number of foods were investigated.

In the case of DBP, consumption approaching the TDI was observed in a small fraction of the population; 1% of respondents (12 individuals) reached nearly 40% of the TDI on an average day. These individuals can be assumed to exceed the TDI occasionally, when consumption of foods with high concentrations is above average.

According to our findings, daily exposure of consumers to phthalates through food does not exceed TDIs. However, this finding is put into perspective by two limiting factors. Firstly, we assessed the consumption of 29 food items. The food list was compiled on the basis of the availability of data on phthalate concentrations, and a compromise regarding the length of the

[2] To compare our results to other studies which report external doses, we neglect the constant for the gastro-intestinal uptake rate (r_{GI}), which is 0.95 for DEHP, 0.73 for DEP and DBP and 0.78 for BBP (Wormuth, et al., 2006).

questionnaire (and resulting motivation in responding to the survey) had to be made. In reality, consumers eat a much broader range of foods than those included in our food frequency questionnaire, and thus they consume more phthalates than our modelled exposure predicted. Secondly, we assumed intermediate phthalate concentrations in the foods. There is considerable variation between surveys in measured phthalate concentrations. For example, the median concentration of DEHP for sweets as used in our study is 237.5µg/kg, while the high concentration (95th percentile) is 2,520µg/kg. Thus, using the high concentrations, closer approximations to the TDIs might have been observed.

Altogether, our data indicate that for the general population there is no phthalate-associated health risk through food. This conclusion should be drawn with caution, as we might have underestimated the true exposure. We identified a small fraction of the population that is likely to occasionally exceed the TDI for DBP.

4.2 Relationships Between Psychological Variables and Phthalate Exposure

We showed that consumer risk perceptions of chemicals in food, natural product interest, general health interest and phthalate exposure were positively related in the case of BBP, DEHP and DEP. For example, BBP exposure through food was related to higher risk perceptions from additives and contaminants and a higher natural product and general health interest. Thus, we identified surprising relationships between subjective and objective dimensions of chemical exposure, which led us to look for the behavioural link between the psychological variables and phthalate exposure.

We identified four diet clusters on the basis of a food frequency questionnaire. The Healthy and Natural and Healthy and Supplements clusters were characterized by consumption of fruit and vegetables, nuts, grains and fibre- briefly, healthy foods. The Health-Passive cluster showed low consumption of all foods, particularly fruit, vegetables and dairy products. The Fat, Sweet and Ready-Meal cluster showed highest consumption of most foods. There were more women and older participants in the two health-oriented clusters than in the other clusters, which is in line with previous studies (Johansson, Thelle, Solvoll, Bjorneboe, & Drevon, 1999; Lennernäs, et al., 1997; Roininen, et al., 1999; Turrell, 1997; Wardle et al., 2004).

Significant differences between clusters in exposure to some phthalates, in natural and health interest and risk perceptions supported the bivariate correlations that we observed between psychological variables and phthalate exposure. The Healthy and Natural and Healthy and Supplements clusters showed higher risk perceptions of contaminants in food and higher interest in natural and healthy foods than the two other clusters. These two clusters were more exposed to BBP than the others, which is probably due to the relatively high median concentrations of BBP in whole wheat bread and in cereals. In turn, the health-passive cluster, which showed low risk perceptions of food chemicals and lowest interest in natural products and general health, was least exposed to all phthalates. The Fat, Sweet and Ready-Meal group showed moderate natural product and general health interest. This cluster was most exposed to DEHP, DBP and DEP, which is in line with their high consumption of most foods in the food frequency questionnaire.

The highest approach to a TDI was observed for the Fat, Sweet and Ready-Meal cluster for DBP, where average daily consumption represented 5.2% of the TDI. In line with the conclusion drawn for the general population, our data does not indicate a health risk for any subgroup. Based on recent evidence, though, a cumulative health risk from exposure to different phthalates may exist (Commitee on the Health Risks of Phthalates, 2008; Howdeshell et al., 2008). In our study, the Fat, Sweet and Ready-Meal and the Healthy and

Supplements clusters were more exposed than the other two clusters to DEHP and DBP, two diesters with significant developmental toxicity. Because a common TDI is lacking for different phthalates exhibiting the same mode of action in developmental toxicity (Commitee on the Health Risks of Phthalates, 2008), we are however not in a position to evaluate cumulative health risk for these diet clusters.

In summary, we observed food-related phthalate exposure in all diet clusters. We found that those clusters that showed a high interest in a natural and healthy diet and who made respective food choices were not less exposed than consumers assigned to the Health-Passive cluster, who showed lower concerns about food chemicals. Health risk does not seem to exist for any of the four diet clusters if phthalates are considered separately. Cumulative health risk assessment merits further investigation, especially when taking into account that consumers receive exposure to phthalates from other sources than food (Wormuth, et al., 2006), that other antiandrogenic chemicals might add to the effects of phthalates (Commitee on the Health Risks of Phthalates, 2008), and that we might have underestimated exposure through food for the reasons mentioned above.

4.3 Implications for Consumer Information and Risk Management

In the context of food chemicals such as additives or agricultural chemicals, consumers can take an informed decision regarding their exposure, and they can reduce their exposure by choosing organic food products. The question is which information about phthalates in food should be available for consumers. On one hand, consumers should be able to learn which chemicals they are ingesting. On the other hand, telling consumers that the only way to reduce exposure is ceasing to consume foods with high median concentrations altogether may have absurd consequences, such as if consumers cease consuming whole wheat bread which otherwise provides a health benefit through fibre (Kuttschreuter, 2006). We propose that the best solution might be to communicate to consumers their phthalate exposure, but with emphasis on the fact that to date there is no evidence of a substantial health risk through food consumption.

The core of the problem lies with the presence of phthalates in the food chain. This underlines the importance of regulations, such as the restriction of phthalate use in food contact materials by the European Food Safety Agency. As food monitoring and biomonitoring studies continue to indicate, however, retail foods still contain phthalates. Many uncontrolled and unforeseeable sources of phthalates in food exist and many food products are imported from countries where regulations and control mechanisms may not be strictly enforced (Kantonales Labor Zürich, 2006; Royal Society of Chemistry, 2006). On one hand, this highlights the role of continuous food product monitoring for environmental contaminants and food contact chemicals, especially with imported products. On the other hand, this indicates that additional efforts are needed to sensitise all stakeholders along the food production chain regarding the potential sources of contamination of their products. Research should focus on identification of all potential sources. Only then is a substantial removal from the market of products containing high levels of phthalates achievable.

4.4 Limitations

Two uncertainty factors in our model (choice of food items, phthalate concentration data), probably leading to underestimation of phthalate exposure, have been discussed above. It might be argued that our phthalate exposure model is further compromised as we used phthalate concentration data from foreign surveys. More accurate exposure models could be created if current data on phthalate concentrations in Swiss food was available; however, to date such data from Switzerland are anecdotal and unsystematic.

We cannot exclude the possibility that over- and underreporting produced a slight bias in food frequency data, especially in the Health-Passive and the Sweet, Fat and Ready-Meal clusters. Nevertheless, the cluster characteristics observed at the psychological level and the demographic differences between clusters indicate validity of the clusters.

It could be argued that the correlation coefficients between psychological variables and phthalate exposure and their effect sizes, which are low to medium according to Cohen (1988), are too low to carry substantive meaning. We recognize that the correlations are low, but the absolute size of these correlations does not affect our findings that all subgroups of the population are exposed to phthalates, even those who particularly care about natural and healthy diets.

4.5 Future Perspectives

Given more current data on phthalate concentrations in food products available in Switzerland, a more complete food frequency questionnaire could be created, diet clusters could be better characterized, and phthalate exposure could be more accurately modelled.

Quantification of consumer exposure to sources of phthalates other than food, such as house dust and personal care products, and the identification of more highly exposed subgroups would be relevant for comprehensive risk assessment and for prevention of phthalate-associated health risks. The combination of single source exposure studies with biomonitoring data would allow the assessment of the relative contribution of these sources to total exposure to phthalates and possibly provide information on unknown sources of exposure.

5 Conclusion

In summary, we showed that all consumers are exposed to phthalates, whether they are pursuing a diet emphasizing natural or healthy foods, or whether they are more careless with regard to these aspects of diet. Thus, our findings illustrate the divergence between consumers' perceptions and interests, and the physical reality. Our results further highlight the relevance of restrictions and control of phthalate use in food contact materials.

References

Bornehag, C. G., Lundgren, B., Weschler, C. J., Sigsgaard, T., Hagerhed-Engman, L., & Sundell, J. (2005). Phthalates in indoor dust and their association with building characteristics. *Environmental Health Perspectives, 113*(10), 1399-1404.

Brug, J., Debie, S., Vanassema, P., & Weijts, W. (1995). Psychosocial determinants of fruit and vegetable consumption among adults - Results of focus group interviews. *Food Quality and Preference, 6*(2), 99-107.

Bundesamt für Statistik. (2009). Statistik des jährlichen Bevölkerungsstandes (ESPOP) 2009: Definitive Ergebnisse. Retrieved from http://www.bfs.admin.ch/bfs/portal/de/index/news/publikationen.html?publicationID=4025

Bundesforschungsinstitut für Ernährung und Lebensmittel. (2008). *Nationale Verzehrsstudie II, Ergebnisbericht, Teil 1*. Karlsruhe, Germany: Author. Retrieved from http://www.was-esse-ich.de/uploads/media/NVS_II_Abschlussbericht_Teil_1_mit_Ergaenzungsbericht.pdf

Castle, L., Mercer, A. J., Startin, J. R., & Gilbert, J. (1988). Migration from plasticized films into foods. 3. Migration of phthalate, sebacate, citrate and phosphate-esters from films used for retail food-packaging. *Food Additives and Contaminants, 5*(1), 9-20.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Colon, I., Caro, D., Bourdony, C. J., & Rosario, O. (2000). Identification of phthalate esters in the serum of young Puerto Rican girls with premature breast development. *Environmental Health Perspectives, 108*(9), 895-900.

Commitee on the Health Risks of Phthalates. (2008). *Phthalates and cumulative risk assessment: The task ahead*. Washington, DC: The National Academies Press.

European Commission. (2004). Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC. *Official Journal of the European Union L338*, 4-17.

European Commission. (2006). *Special Eurobarometer: Health and food* (246- Wave 64.3.). Retrieved from http://ec.europa.eu/health/ph_publication/eb_food_en.pdf

European Economic Community. (2006). Council Regulation (EEC) No 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. *Official Journal of the European Union L198, p. 1 of 22.7.1991*. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1991R2092:20060506:EN:PDF.

European Food Safety Agency. (2005a). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to bis(2-ethylhexyl)phthalate (DEHP) for use in food contact materials. Retrieved from http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1178620770530.htm

European Food Safety Agency. (2005b). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to Butylbenzylphthalate (BBP) for use in food contact materials. Retrieved from http://www.efsa.europa.eu/en/efsajournal/doc/241.pdf

European Food Safety Agency. (2005c). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to di-

Butylphthalate (DBP) for use in food contact materials. Retrieved from http://www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1178620770694.htm

Field, A. (2005). *Discovering statistics using SPSS*. London, England: SAGE Publications.

Frewer, L. J., & Miles, S. (2001). Risk perception, communication and trust. How might consumer confidence in the food supply be maintained? In L. J. Frewer, E. Risvik & H. Schifferstein (Eds.), *Food, People and Society* (pp. 401-414). Berlin, Germany: Springer.

Fromme, H., Gruber, L., Schlummer, M., Wolz, G., Bohmer, S., Angerer, J., . . . Bolte, G. (2007). Intake of phthalates and di(2-ethylhexyl)adipate: results of the Integrated Exposure Assessment Survey based on duplicate diet samples and biomonitoring data. *Environment International, 33*(8), 1012-1020.

Gray, L. E., Ostby, J., Furr, J., Price, M., Veeramachaneni, D. N. R., & Parks, L. (2000). Perinatal exposure to the phthalates DEHP, BBP, and DINP, but not DEP, DMP, or DOTP, alters sexual differentiation of the male rat. *Toxicology Sciences, 58*, 350-365.

Hauser, R., & Calafat, A. M. (2005). Phthalates and human health. *Occupational and environmental medicine, 62*, 806-818.

Heudorf, U., Mersch-Sundermann, V., & Angerer, J. (2007). Phthalates: Toxicology and exposure. *International Journal of Hygiene and Environmental Health, 210*(5), 623-634.

Howdeshell, K. L., Wilson, V. S., Furr, J., Lambright, C. R., Rider, C. V., Blystone, C. R., . . . Gray, L. E. (2008). A mixture of five phthalate esters inhibits fetal testicular testosterone production in the sprague-dawley rat in a cumulative, dose-additive manner. *Toxicological Sciences, 105*(1), 153-165.

Johansson, L., Thelle, D. S., Solvoll, K., Bjorneboe, G. E. A., & Drevon, C. A. (1999). Healthy dietary habits in relation to social determinants and lifestyle factors. *British Journal of Nutrition, 81*(3), 211-220.

Kantonales Labor Zürich. (2006). *Jahresbericht 2006*. Zürich, Switzerland: Author. Retrieved from http://www.klzh.ch/downloads/JB_2006_KLZH.pdf

Koch, H. M., Becker, K., Wittassek, M., Seiwert, M., Angerer, J., & Kolossa-Gehring, M. (2007). Di-n-butylphthalate and butylbenzylphthalate – urinary metabolite levels and estimated daily intakes: pilot study for the German Environmental Survey on children. *Journal of Exposure Science and Environmental Epidemiology, 17*(4), 378-387.

Koch, H. M., Drexler, H., & Angerer, J. (2003). An estimation of the daily intake of di(2-ethylhexyl)phthalate (DEHP) and other phthalates in the general population. *International Journal of Hygiene and Environmental Health, 206*(2), 77-83.

Kuchen, A., Müller, F., Farine, M., Zimmermann, H., Blaser, O., & Wüthrich, C. (1999). Die mittlere tägliche Aufnahme von Pestiziden und anderen Fremdstoffen über die Nahrung in der Schweiz. *Mitteilungen aus Lebensmitteluntersuchung und Hygiene, 90*, 78-107.

Kuttschreuter, M. (2006). Psychological determinants of reactions to food risk messages. *Risk Analysis, 26*(4), 1045-1057.

Latini, G., De Felice, C., Presta, G., Del Vecchio, A., Paris, I., Ruggieri, F., & Mazzeo, P. (2003). In utero exposure to di-(2-ethylhexyl)phthalate and duration of human pregnancy. *Environmental Health Perspectives, 111*(14), 1783-1785.

Lennernäs, M., Fjellström, C., Becker, W., Giachetti, I., Schmitt, A., Remaut de Winter, A., & Kearney, M. (1997). Influences on food choice perceived to be important by nationally-representative samples of adults in the European Union. *European Journal of Clinical Nutrition, 51*(Suppl. 2), S8-15.

McNaughton, S. A., Ball, K., Mishra, G. D., & Crawford, D. A. (2008). Dietary patterns of adolescents and risk of obesity and hypertension. *The Journal of Nutrition, Nutritional Epidemiology, 138*, 364-370.

Miles, S., Brennan, M., Kuznesof, S., Ness, M., Ritson, C., & Frewer, L. J. (2004). Public worry about specific food safety issues. *British Food Journal, 106*(1), 9-22.

Ministry of Agriculture Fishery and Food. (1996). Information sheet No. 168: Phthalates in Food. Retrieved from http://archive.food.gov.uk/maff/archive/food/infsheet/1998/no168/168phtha.htm

Mylchreest, E., Cattley, R. C., & Foster, P. M. D. (1998). Male reproductive tract malformations in rats following gestational and lactational exposure to di(n-butyl) phthalate: an antiandrogenic mechanism? *Toxicological Sciences, 43*, 47-60.

Peijnenburg, W. J. G. M., & Struijs, J. (2006). Occurrence of phthalate esters in the environment of the Netherlands. *Ecotoxicology and Environmental Safety, 63*, 204-215.

Petersen, J. H., & Breindahl, T. (2000). Plasticizers in total diet samples, baby food and infant formulae. *Food Additives and Contaminants, 17*(2), 133-141.

Pollard, J., Kirk, S. F. L., & Cade, J. E. (2002). Factors affecting food choice in relation to fruit and vegetable intake: a review. *Nutrition Research Reviews, 15*(2), 373-387.

Raats, M. M., & Shepherd, R. (1996). Developing a subject-derived terminology to describe perceptions of chemicals in foods. *Risk Analysis, 16*(2), 133-146.

Roininen, K., Lahteenmaki, L., & Tuorila, H. (1999). Quantification of consumer attitudes to health and hedonic characteristics of foods. *Appetite, 33*(1), 71-88.

Royal Society of Chemistry. (2006). Contamination from food packaging 'ignored', from http://www.rsc.org/chemistryworld/Issues/2006/October/ContaminationFoodPackaging.asp

Rudel, R. A., Camann, D. E., Spengler, J. D., Korn, L. R., & Brody, J. G. (2003). Phthalates, alkylphenols, pesticides, polybrominated diphenyl ethers, and other endocrine-disrupting compounds in indoor air and dust. *Environmental Science & Technology, 37*(20), 4543-4553.

Schulze, M. B., & Hoffmann, K. (2006). Methodological approaches to study dietary patterns in relation to risk of coronary heart disease and stroke. *British Journal of Nutrition, 96*, 860-869.

Siegrist, M., Keller, C., & Kiers, H. A. L. (2005). A new look at the psychometric paradigm of perception of hazards. *Risk Analysis, 25*(1), 211-222.

Siegrist, M., Keller, C., & Kiers, H. A. L. (2006). Lay people's perception of food hazards: Comparing aggregated data and individual data. *Appetite, 47*(3), 324-332.

Silva, M. J., Barr, D. B., Reidy, J. A., Malek, N. A., Hodge, C. C., Caudill, S. P., . . . Calafat, A. M. (2004). Urinary levels of seven phthalate metabolites in the US population from the National Health and Nutrition Examination Survey (NHANES) 1999-2000. *Environmental Health Perspectives, 112*(3), 331-338.

Sparks, P., & Shepherd, R. (1994). Public perceptions of the potential hazards associated with food-production and food-consumption - an empirical study. *Risk Analysis, 14*(5), 799-806.

Swan, S. H., Main, K. M., Liu, F., Stewart, S. L., Kruse, R. L., Calafat, A. M., . . . Teague, J. L. (2005). Decrease in anogenital distance among male infants with prenatal phthalate exposure. *Environmental Health Perspectives, 113*(8), 1056-1061.

Turrell, G. (1997). Determinants of gender differences in dietary behavior. *Nutrition Research, 17*(7), 1105-1120.

US Environmental Protection Agency. (1993). Diethyl phthalate (CASRN 84-66-2), from http://www.epa.gov/iris/subst/0226.htm von Alvensleben, R. (2001). Beliefs associated with food production methods. In L. J. Frewer, E. Risvik & H. Schifferstein (Eds.), *Food, People and Society*. Berlin, Heidelberg: Springer.

Waijers, P. M. C. M., Ocké, M. C., van Rossum, C. T. M., Peeters, P. H. M., Bamia, C., Chloptsios, Y., . . . Bueno-de-Mesquita, H. B. (2006). Dietary patterns and survival in older Dutch women. *American Journal of Clinical Nutrition, 83*, 1170-1176.

Wardle, J., Haase, A. M., Steptoe, A., Nillapun, M., Jonwutiwes, K., & Bellisle, F. (2004). Gender differences in food choice: The contribution of health beliefs and dieting. *Annals of Behavioral Medicine*, *27*(2), 107-116.

Wittassek, M., Heger, W., Koch, H. M., Becker, K., Angerer, J., & Kolossa-Gehring, M. (2007). Daily intake of di(2-ethylhexyl)phthalate (DEHP) by German children – a comparison of two estimation models based on urinary DEHP metabolite levels. *International Journal of Hygiene and Environmental Healthy, 210*(1), 35-42.

Wormuth, M., Scheringer, M., Vollenweider, M., & Hungerbuhler, K. (2006). What are the sources of exposure to eight frequently used phthalic acid esters in Europeans? *Risk Analysis*, *26*(3), 803-824.

Chapter III

Attitudes Toward Chemicals are Associated With Preference for Natural Food

Abstract

Consumers express concerns about chemicals in their diet. We hypothesized that general positive and negative attitudes toward synthetic chemicals and dose-response insensitivity influence consumers' risk perceptions of chemicals in food and preference for natural food. We expected gender differences in these domains. Data was taken from a postal survey. Structural equation modelling was used to test our hypotheses. Positive attitudes toward chemicals were correlated negatively, and dose-response insensitivity was correlated positively, with risk perceptions of chemicals in food. Risk perceptions of chemicals in food were positively correlated with preference for natural food. For all variables, gender differences were observed. Our findings show that general attitudes toward chemicals influence perceptions in the food context. Consumers' dose-response insensitivity might lead to an inappropriate perception of exposure hazards. Contaminants and additives in food are perceived differently according to their origin. Women are more sensitive than men to chemical exposure hazards.

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1 Introduction

The origin of synthetic chemicals in food is manifold. Flavourings, colourings and preservatives are added to food to modify its organoleptic qualities, to improve its nutritive value or to enhance convenience for the consumer (Branen, Davidson, Salminen, & Thorgate III, 2002). Other chemicals, such as pesticides or antibiotics, serve to optimize the production process by supporting abundance or diversity (Branen, et al., 2002). They may enter the food at some stage between farm and fork, and they can remain in food as residuals. Still other chemicals in food originate from environmental sources, such as dioxins.

Meanwhile, numerous surveys have shown that consumers are worried about being exposed in their daily diet to synthetic chemicals (Bundesforschungsinstitut für Ernährung und Lebensmittel, 2008; European Commission, 2006; Miles et al., 2004) and the organic food market has grown considerably in recent years (Dimitri & Greene, 2002; Hamm, Gronefeld, & Halpin, 2002).

The first aim of this study was to examine whether consumer risk perception of chemicals in food and preference for natural foods originate from more general attitudes toward chemical exposure and from consumers' understanding of chemical dose-response relationships. We used structural equation modelling to examine these relationships. The second aim was to examine gender differences in attitudes toward chemicals and preference for natural food.

1.1 Risk Perception of Chemicals

Consumers are concerned about exposure to chemicals. One-third of European consumers selected "The impact on our health of chemicals used in everyday products" among the environmental issues that caused the greatest worry in 2004 and 2007 (European Commission, 2004, 2008).

Two studies (Kraus, Malmfors, & Slovic, 2001; MacGregor, Slovic, & Malmfors, 1999) investigated laypeople's understanding of toxicological concepts and attitudes toward chemicals. Laypeople's perception was characterized by insensitivity to dose-response relationships. Laypeople viewed chemicals as either safe or dangerous, and thought that minor doses of chemicals were likely to cause harm. This idea was associated with strongly negative attitudes toward chemicals. Laypeople stated concern about small amounts of chemicals in groundwater and food, agreed that contamination was greater than ever before and indicated that the worst was yet to come with regard to chemical risks. In line with these negative attitudes, laypeople supported chemical risk reduction at all costs, laypeople did everything they could to avoid chemical risks and many required use of chemicals to be absolutely risk-free.

1.2 Preference for Natural Food and its Determinants

The word natural evokes mostly positive associations in consumers (Rozin, Fischler & Shields (2005) in Rozin, 2005), and they often see natural entities as inherently better than non-natural entities (Rozin, 2005).

From a consumer perspective, there is a large overlap between the concepts of natural food and organic food. Organic foods are believed to be free of synthetic chemicals, and are regarded as healthier than non-organic foods (Grankvist & Biel, 2001; Schifferstein & Ophuis, 1998; von Alvensleben, 2001). Furthermore, organic foods are seen as more environmentally friendly than conventionally produced foods (Grankvist & Biel, 2007).

Consumers judge naturalness of foods based on the history of a food item rather than its actual content (Rozin, 2006). Research suggests that various factors influence consumer interest in a natural diet. Researchers have shown that concerns about health are the main reason for purchasing organic foods (Magnusson, Arvola, Hursti, Aberg, & Sjoden, 2003; Schifferstein & Ophuis, 1998). Higher risk perceptions of industrially produced and processed foods and perceived benefits of organic foods were related to higher organic food consumption (Lockie, Lyons, Lawrence, & Grice, 2004). Consumers with a higher number of modern health worries, such as “depletion of the ozone layer”, “drug-resistant bacteria”, “pesticides in food” or “cell phones” showed a stronger preference for foods that had only natural ingredients (Devcich, Pedersen, & Petrie, 2007).

One study showed that consumers preferred natural foods and medicines to their artificial counterparts regardless of healthfulness (Rozin et al., 2004); thus, other motives than health also seem to support organic food consumption. The value Universalism was associated with positive attitudes toward organically grown foods and selection of organic and free-range meat (de Boer, Hoogland, & Boersema, 2007; Dreezens, Martijn, Tenbult, Kok, & de Vries, 2005a, 2005b). Universalism is a value that describes the priority given by a person to universal values such as social justice or unity with nature (Schwartz et al., 2001).

High food involvement, i.e. the level of importance of food in a person’s life, played a role in organic food selection and in having “natural content” as a food choice motive (de Boer, et al., 2007; Eertmans, Victoir, Vansant, & Van den Bergh, 2005). Similarly, giving more importance to the sensory and emotional experience of eating, i.e. eating food that makes one feel good, was related to higher organic food consumption (Lockie, et al., 2004).

Schifferstein and Ophuis (1998) showed that organic food buyers found themselves more responsible for their own health, knew more about nutrition and were more willing to sacrifice money, appearance and time for food than non-organic food buyers. Organic food buyers were also more interested in nature, society, economics and politics, and were more oriented toward self-fulfilment, excitement and self-respect. Therefore, organic food consumption seems to be part of a lifestyle that results from an underlying ideology, rather than from a specific desire (Schifferstein & Ophuis, 1998).

1.3 Gender Differences in Risk Perception and Preference for Natural Food

The fact that women perceive higher risk from most hazards than men has been long-standing. For example, women express more concern about technological and environmental risks such as gene technology or nuclear waste (Siegrist, 2000; Slovic, 2001). Similarly, women in Europe were more concerned about the effects of chemicals on health, compared to men (European Commission, 2004). In the context of food, women showed more concern than men about risks such as bacteria, additives, pesticides and fat (Dosman, Adamowicz, & Hrudey, 2001; Knight & Warland, 2004).

Two possible explanations for this finding are considered the most plausible (Davidson & Freudenburg, 1996). First, it has been suggested that women are more concerned with health and safety because they are socialized to nurture and maintain life. Second, men tend to have higher trust than women in institutions involving science, technology and the government, and higher trust is known to imply lower environmental concern (Davidson & Freudenburg, 1996).

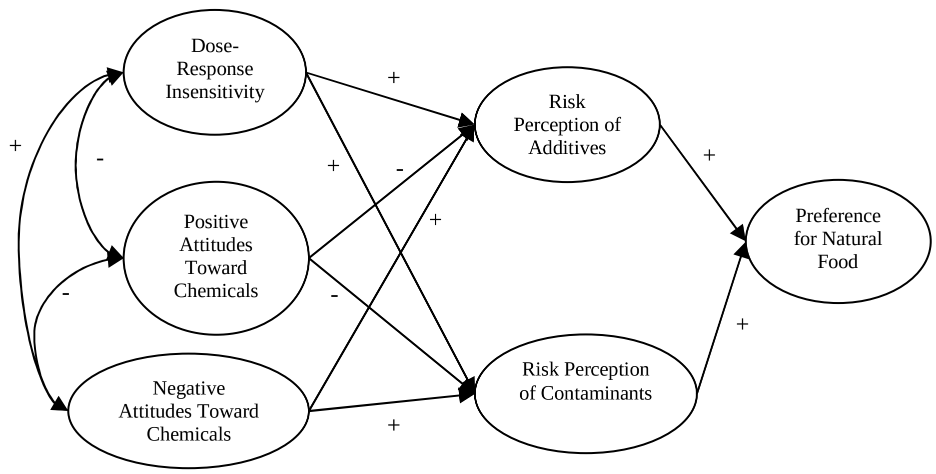
In accordance with gender differences in perception of food and chemical risks, there is also evidence of a gender bias in preference for natural food. Lockie et al. (2004) identified a gender basis underlying organic food consumption. Roininen, Lahteenmaki and Tuorila (1999) reported women to be more interested than men in the health and natural aspects of food. Other studies observed higher numbers of women in consumer groups with a stronger interest in eating a natural diet or in customer groups of organic food stores (Dickson-Spillmann, Siegrist, Keller, & Wormuth, 2009; Schifferstein & Ophuis, 1998).

1.4 Rationale for the Present Study

The key idea of our hypothesized model is that general attitudes toward chemicals influence more specific perceptions of chemicals in diet and preference for natural food. Our proposed model, including the expected directions of the relationships between variables, is shown in Figure 3.1.

In this study, we label synthetic flavourings, colorants and preservatives additives, while we summarize pesticides, antibiotic residues and dioxins as contaminants. We assumed that dose-response insensitivity and positive and negative attitudes toward chemicals influence the risk perception of contaminants and additives in food. Higher dose-response insensitivity was expected to lead to higher fear of chemical contact and therefore to higher risk perception of additives and contaminants in food. More positive general attitudes toward chemicals and weaker negative attitudes were thought to lower risk perception of additives and contaminants in food. The distinction between positive and negative attitudes was based on previous work in consumer perception of food safety (de Jonge, 2008) and in other consumer behaviour domains (Cacioppo, Gardner, & Berntson, 1997; Conner & Sparks, 2002; Poortinga & Pidgeon, 2003). These studies found that optimistic and pessimistic perceptions of consumer issues were not mutually exclusive. Optimistic and pessimistic perceptions loaded on distinct factors, highlighting that consumers might see positive aspects despite having concerns (de Jonge, 2008).

Figure 3.1: Initial (Hypothesized) Model of the Determinants of the Preference for Natural Food



We assumed that dose-response insensitivity and attitudes toward chemicals would exert weaker influences on the risk perception of additives than of contaminants. This hypothesis was based on the different origin of these chemicals in food. Additives are added to food on a highly regulated and intentional basis to provide a consumer benefit (Branen, et al., 2002; Bundesamt für Gesundheit, 2007). Meanwhile, agricultural and environmental chemicals (contaminants) in food are often unwanted, but unavoidable, by-products of production processes; some, such as the environmental chemical dioxin, may even enter foods via entirely unknown and uncontrolled pathways (European Commission, 2001; Sparks &

Shepherd, 1994). We expected higher risk perceptions of contaminants and additives to enhance the preference for natural food.

Based on the reviewed literature, we hypothesized that men and women would differ in attitudes toward chemicals, risk perceptions of contaminants and additives in food and preference for natural food. We expected women to have more negative attitudes, higher risk perceptions and a stronger preference for natural food than men.

2 Methods

2.1 Participants

The data for the present study come from a mail survey conducted in the German-speaking part of Switzerland. A random sample of 3,000 households received a questionnaire. The person in the household over 18 years of age whose birthday was next was asked to fill in the questionnaire. The response rate was 40.5% (N = 1,215).

The mean age of respondents was 53.2 (15.9) years. Forty-nine percent (n = 601) were female, and 51% (n = 614) were male.

2.2 Questionnaire

The questionnaire was designed to measure general attitudes toward chemicals, risk perception of various chemicals in food and preference for natural food. Once the data was collected, reliability analyses were conducted on the hypothesized scales. Those items that contributed to increasing internal consistency as measured by Cronbach's α were used for scale construction. The scales are described below.

2.2.1 Dose-Response Insensitivity

Questions about dose-response insensitivity assessed whether the person perceived being in contact with chemicals, regardless of the dose, as dangerous (Table 3.1). Two items (V1, V3) were taken from the work of Kraus et al. (2001), and two other items (V2, V4) were added to the scale. Responses to the questions were given on 6-point scales ranging from 1 (don't agree at all) to 6 (totally agree).

2.2.2 Positive Attitudes Toward Chemicals

General positive attitudes toward chemicals were ascertained. On one hand, questions assessed the acceptance of chemicals as they support health and advancement (V5 and V8). On the other hand, carelessness about chemical risks was measured (V6, V7 and V9).

All items but V9 were adopted from the work of Kraus et al. (2001). Item V8 "Chemicals are a major force behind technological advancement" was re-formulated as "Chemicals play an important role for the advancement of society" because laypeople were thought to be more familiar with issues regarding society rather than technology.

2.2.3 Negative Attitudes Toward Chemicals

Four questions were designed to measure negative attitudes toward chemicals. Questions assessed fear of chemicals (V10), motivation to avoid chemicals (V11, V13) and the demand for complete absence of chemical risks (V12). V11 and V12 were borrowed from the work of Kraus et al. (2001).

2.2.4 Risk Perception of Food Chemicals

Risk perception of six chemicals in food was assessed. The chemicals belonged to two categories, additives (preservatives, artificial colourings, artificial flavourings) and contaminants (pesticides, antibiotics, dioxins). Risk perception was indicated on a scale from 1 (*no risk*) to 6 (*high risk*), with the option of responding don't know this chemical.

2.2.5 Preference for Natural Food

Preference for natural food was assessed using the Natural Product Interest subscale from the Health and Taste Attitudes Questionnaire proposed by Roininen et al. (1999). Answers were given on 6-point scales ranging from 1 (*don't agree at all*) to 6 (*totally agree*).

2.3 Structural Equation Modelling Procedure

The variables used to measure the six constructs of the causal model (latent variables), their factor loadings and scale reliabilities are shown in Table 3.1. Confirmatory factor analyses were conducted in AMOS 16.0 (SPSS Inc.) for each latent variable. All factor loadings were significant ($p < .001$) and substantial (> .40 or < -.40), confirming the appropriateness of the measurement model.

Table 3.1: Latent Constructs, Reliabilities, Indicator Variables Used for Testing the Causal Model, and Factor Loadings of the Final Model

Factors and variables	Factor loadings
Dose-Response Insensitivity; α = .77	
V1 If you are exposed to a toxic chemical substance, then you are likely to suffer adverse health effects.	.61
V2 Being exposed to carcinogens is always dangerous, no matter what the dose of the agent.	.81
V3 With toxic chemical substances, it's not how much of the chemical you are exposed to that should worry you, but whether or not you are exposed to it at all.	.78
V4 If you don't want to become ill, you should avoid any contact with toxic chemical substances.[a]	.55
Positive Attitudes Toward Chemicals; α = .71	
V5 Use of chemicals has improved our health more than has harmed it.	.52
V6 I am not worried about very small amounts of chemical substances found in groundwater and in food.	.67
V7 People worry unnecessarily about what chemicals can do to their health.	.50
V8 Chemicals play an important role for the advancement of society. [a]	.52
V9 Our society has to deal with more important risk than chemical risks.	.45
Negative Attitudes Toward Chemicals; α = .76	
V10 I am scared of chemical substances and the risks associated with them.	.71
V11 I do everything I can to avoid contact with chemicals and chemical products in my daily life.	.74
V12 All use of chemicals must be risk free.	.57
V13 I would like to live in a world where chemicals do not exist. [a]	.64

Factors and variables	Factor loadings
Risk Perception of Additives; α = .83	
V14 Synthetic preservatives [a]	.87
V15 Synthetic colorants	.78
V16 Synthetic flavours	.73
Risk Perception of Contaminants; α = .76	
V17 Pesticides [a]	.70
V18 Antibiotic residues in meat	.76
V19 Dioxins	.71
Preference for Natural Food; α = .73	
V20 I do not care about additives in my daily diet.	-.64
V21 I try to eat foods that do not contain additives.	.77
V22 I would like to eat only organically grown vegetables.	.65
V23 I do not eat processed foods, because I do not know what they contain. [a]	.54

Note. Error correlations between V5 and V8, and between V7 and V9 were added during the course of model modification.
[a] Fixed parameter for statistical identification

Structural equation modelling procedures were used to test the plausibility of the postulated causal model. Analyses were based on the raw data. The maximum likelihood estimator was used. Assessment of model fit was based on the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA) and the substantive interpretability of the model. For the CFI, values higher than .90 represent acceptable fit and values higher than .95 good fit; for the RMSEA, values below .08 represent acceptable, values equal or below .05 good fit (Byrne, 2001). Modification indices were used to identify parameter additions that would enhance model fit. Parameters were added in consideration of substantive meaningfulness and parsimony. The level of significance for hypothesis tests was set to α = .05.

Once the general model was established, we tested gender differences in latent variable means. We followed the approach suggested by Byrne (2001). The model was tested for men and women separately before it was fitted to both genders simultaneously. Then, the invariance of the measurement coefficients and causal paths across genders was tested before the latent mean differences were examined.

Participants who answered don’t know this chemical to questions about risk perception of food chemicals were excluded from the structural equation modelling procedures (*n* = 169). Of the remaining 1046 respondents, 89% (*n* = 931) answered all questions used for testing the causal model, 5.6% (*n* = 59) had one missing value and 5.4% (*n* = 56) had two or more missing values. For participants with one missing value, data imputation was performed via regression analysis. Values of the items from the same scale were used as predictors of the missing value. The final dataset used for structural equation modelling included 990 individuals.

3 Results

3.1 General Model of the Influence of Attitudes Toward Chemicals on Risk Perception of Chemicals in Food and Preference for Natural Food

The initial model yielded a suboptimal fit to the data (Table 3.2). The modification indices suggested the addition of two correlations among the error terms of the items belonging to the Positive Attitudes Toward Chemicals scale. This was regarded as a plausible modification. Items V5 and V8 deal with the benefit of chemicals for society, and items V7 and V9 refer to the absence of need to worry about chemicals. The initial model and the revised model with two added error correlations were nested. Thus, the difference in χ^2 between the two models was used for assessing the improvement in fit of the revised model. The addition of the two error correlations dropped the chi-square significantly and improved model fit (Table 3.2).

Modification indices suggested, furthermore, that adding a direct causal path from the latent variable Negative Attitudes Toward Chemicals to Preference for Natural Food would decrease the chi-square. It seems plausible that negative attitudes toward chemicals would directly lead to enhanced preference for natural food, without being mediated by risk perception of chemicals in food. Thus, this path was added to the model. This led to a significant decrease in the chi-square. The modification indices did not suggest the addition of any further meaningful path or covariance to the model. The final model showed an acceptable (CFI) to good (RMSEA) fit (Table 3.2). Three paths were non-significant ($p > .05$): the path from Dose-Response Insensitivity to Risk Perception of Additives and the paths from Negative Attitudes Toward Chemicals to Risk Perception of Additives and Contaminants.

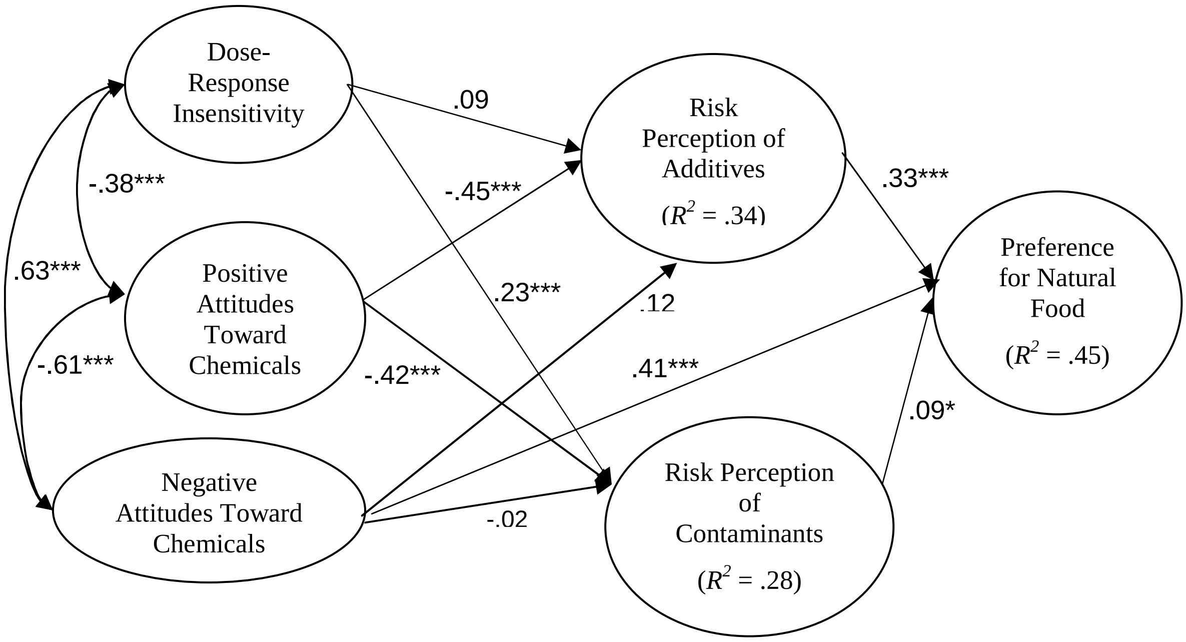
The final model is presented in Figure 3.2. The path estimates represent standardized coefficients. The model explained 28% of variance in Risk Perception of Contaminants, 34% of variance in Risk Perception of Additives and 45% of variance in Preference for Natural Food.

Table 3.2: Test Statistics for the Hypothesized Model

Model	χ^2	*df*	CFI	RMSEA	$\Delta\chi^2$	Δdf	*p*
Initial	950.9	219	.90	.06			
Addition of 2 correlations among error terms[a]	834.9	217	.92	.05	116.0	2	<.01
Addition of path Negative Attitudes → Preference for Natural Food	745.8	216	.93	.05	89.1	1	<.01

[a] e(V5) ⇔ e(V8); e(V7) ⇔ e(V9).

Figure 3.2: Final Model of the Determinants of the Preference for Natural Food. Values Represent Standardized Estimates, N = 990.



Note. Asterisks refer to levels of significance:
* $p < .05$
*** $p < .001$

3.2 Gender Differences

The model was first tested separately in men and women (Byrne, 2001). The model showed a good fit for men and an acceptable to good fit for women (Table 3.3). Thus, the same baseline model was used for men and women.

Table 3.3: Overall Fit Indices for Men and Women (Model Tested Separately in Both Groups)

	N	χ^2	*df*	CFI	RMSEA
Men	509	452.4	216	.94	.05
Women	481	506.2	216	.92	.05

The model was then tested simultaneously in men and women. Analysis indicated an acceptable to good fit (Table 3.4). To test for measurement invariance, in the second step measurement weights were constrained to be equal in both groups. The difference in χ^2 to the unconstrained model was not significant, indicating factor loading invariance across the groups. For the next model, while the measurement weights were held invariant, structural weights were also constrained to equality between the groups. Again, the increase in χ^2 was not significant, demonstrating that the same causal model explained the preference for natural food in men and women.

Table 3.4: Tests for Equality Across Gender (Model Tested Simultaneously in Both Groups)

	χ^2	*df*	CFI	RMSEA	$\Delta\chi^{2\,a}$	Δdf	*p*
Initial model without constraints	958.6	432	.93	.04			
Equality constraints on measurement weights	978.1	449	.93	.04	19.5	17	0.30
Equality constraints on structural weights	999.6	461	.93	.03	41.0	29	0.07

[a]$\Delta\chi^2$ compared to the baseline model according to the procedure recommended by Byrne (2001)

Differences between the genders in the latent means were then tested. In addition to measurement and structural weights, intercepts for the observed indicators were constrained to equality across the groups. The latent means and intercepts were freely estimated in men and constrained to zero in women. The model showed an acceptable to good fit (CFI= .92, RMSEA= .04, $\chi^2(475) = 1071.0$). The χ^2 increase compared to the baseline model was significant ($\Delta\chi^2(43) = 112.4$, $p < .01$), but the modification indices showed only minor χ^2 changes associated with relaxing the two item intercepts equality constraints. Thus, we proceeded to the interpretation of the mean differences.

Table 3.5 shows the mean differences of the latent variables between men and women. Men showed significantly lower dose-response insensitivity, more positive and weaker negative attitudes toward chemicals than women.

For the latent endogenous variables (risk perception of contaminants and additives, and preference for natural food), the adjusted and raw means were calculated. The adjusted means represent mean differences when differences in exogenous latent variable means are controlled for; i.e., structural path weights are held invariant across the groups. The raw means were calculated by setting all structural path weights to zero, thereby eliminating the effects of structural paths.

The raw means showed that men had significantly lower risk perceptions of contaminants and additives than women (Table 3.5). The adjusted means indicated that when gender differences in Positive Attitudes Toward Chemicals were factored out, men and women did not differ in risk perception of contaminants and additives. This indicated that the raw mean differences in chemical risk perception were due to the influence of general positive attitudes toward chemicals.

The raw mean difference indicated a weaker preference for natural food in men compared to women. This difference persisted when the adjusted mean (i.e. the influences of Risk Perception of Contaminants and Additives, and Negative Attitudes Toward Chemicals factored out) was considered. Thus, the difference in Preference for Natural Food was not solely explained by these influences.

Table 3.5: Differences in the Means and Intercepts of the Latent Variables for Men, with Women as the Reference Group (Standard Errors in Brackets)

Latent variable	Mean difference	*p*		*p*
Dose-Response Insensitivity	-.26 (.07)	<.01		
Negative Attitudes	-.45 (.09)	<.01		
Positive Attitudes	.36 (.07)	<.01		
	Raw mean difference		Adjusted mean difference	
Risk Perception Additives	-.33 (.08)	<.01	-.03 (.07)	.67
Risk Perception Contaminants	-.17 (.07)	<.01	.04 (.07)	.52
Preference for Natural Food	-.42 (.07)	<.01	-.21 (.06)	<.01

4 Discussion

Using structural equation modelling, we showed that consumers' dose-response insensitivity and positive attitudes toward chemicals influence consumers' risk perception of chemicals in food. These risk perceptions, in turn, determine consumers' preference for natural food. Further, we showed that negative attitudes toward chemicals affect preference for natural food. Women have lower positive and higher negative attitudes toward chemicals than men, and women score higher in dose-response insensitivity, risk perceptions of chemicals in food and preference for natural food. Our findings provide new evidence about the origin of consumer preference for natural food, and they allow us to draw conclusions for risk communication.

4.1 The Influence Model

In line with our expectations, positive consumer attitudes toward chemicals affected risk perceptions of contaminants and additives in food. Consumers who saw more benefits in chemicals, who did not regard tackling chemical risks as a priority and who worried less about the effects of chemicals on health perceived lower risks from chemicals in food. This shows that general optimism about a topic leads to optimism in specific topic-related contexts—even in the food context, which carries high individual significance as food involves the incorporation of potentially dangerous substances into the body (Rozin & Fallon, 1987).

Consumers' insensitivity to dose-response relationships influenced consumers' risk perception of contaminants but not of additives in food. Food additives are among the best-controlled chemicals that consumers are exposed to, and the presence of food additives in foods has to be indicated on food labels throughout the EU and in Switzerland (Bundesamt für Gesundheit, 2007; European Economic Community, 2000). Thus, consumer exposure to food additives is explicit and highly controlled. We suspect that the clarity associated with exposure to additives renders consumers' subjective concepts about chemical dose-response relationships irrelevant in risk perception of food additives.

In line with our expectations, dose-response insensitivity led to higher risk perceptions of contaminants. Exposure to contaminants in food is less explicit than exposure to additives. Consumers have expressed less familiarity with animal medicines and pest control products in food than with synthetic colourings and flavourings (Raats & Shepherd, 1996). Higher scores for contaminants than additives on the Dread Risk dimension were observed in other studies (Raats & Shepherd, 1996; Siegrist, Keller, & Kiers, 2006; Sparks & Shepherd, 1994). In view of the ambiguity associated with exposure to contaminants, we conclude that consumer perception of contaminant risk may be more susceptible to lay interpretations of dose-response relationships than perception of risk through food additives. The role of consumers' dose-response insensitivity in food perception has been confirmed in other studies in which the perceived naturalness or healthfulness of foods was not changed by the dose of an ingredient (Rozin, 2005; Rozin, Ashmore, & Markwith, 1996).

Our model explained 28% of the variance in Risk Perception of Contaminants. This suggests that there are other factors not accounted for by our model that might influence this perception. Such factors include trust in the chemical industry or trait anxiety.

Contrary to our hypothesis, negative attitudes toward chemicals did not show a significant influence on the risk perception of chemicals in food. Instead, negative attitudes toward chemicals directly influenced the preference for natural food. This direct relationship is plausible. For those consumers who fear chemical risks more and who have a higher motivation to avoid and eliminate chemical risks, pursuing a natural diet may be understood as a possibility for reducing exposure to chemical risks. Our findings are in agreement with those of MacGregor et al. (1999). In that study, respondents who reported trying to generally avoid contact with chemicals also reported adherence to specific avoidance behaviours, such as not eating foods with preservatives, not using artificial sweeteners or not using household cleaning products.

The highly significant influence of risk perception of additives on natural food preference suggests that consumers believe that they can control intake of additives by choosing natural food products. In contrast, the small effect of risk perception of contaminants on natural food preference indicates that consumers believe they cannot control intake of contaminants. We conclude that the relationship between the perception of contaminants and additives and preference for natural food merits further investigation.

Risk perception of additives and contaminants, and attitudes toward chemical risk reduction together explained 45% of the variance in the preference for natural food. This finding confirms the importance of risk perception in the preference for natural food. At the same time, this finding may indicate the existence of other determinants of preference for natural food, such as universalism or food involvement (de Boer, et al., 2007; Dreezens, et al., 2005b; Eertmans, et al., 2005).

4.2 Gender Differences

As expected, we observed weaker positive attitudes toward chemicals, lower dose-response sensitivity and higher risk perception of contaminants and additives in women than in men. Further, women showed higher negative attitudes and higher preference for natural food.

Our results are in line with the much-replicated finding that women perceive higher risk from most environmental hazards than men (Slovic, 2001). Our results also overlap with those of Kraus et al. (2001). In that study, women scored lower on selected items about positive attitudes toward chemicals, higher on items about negative attitudes and higher on items about dose-response insensitivity. In our study, we extended Kraus et al.'s analysis by creating reliable scales, and we were able to replicate the gender effects in this statistically more powerful context.

The comparison of adjusted and raw means showed that gender differences in positive attitudes toward chemicals and in dose-response insensitivity explained the differences at the level of chemical risk perception of additives and contaminants. In contrast, gender differences in the preference for natural food persisted when the differences in the risk perception of additives and contaminants were factored out, and in negative attitudes toward chemicals. Therefore, we assume that gender differences in other determinants of the preference for natural food, such as universalism or food involvement, may lead to differences in the preference for natural food.

4.3 Implications for Risk Communication

Our findings show that consumer preference for natural food results from a cascade of perceptions about chemicals, starting with general attitudes and understanding of dose-response relationships. What implications do these findings yield for consumer risk communication? First, our findings emphasize the importance of dose-response perceptions in consumer reactions to chemicals in food. Consumers who are dose-response insensitive may easily overreact to stories about chemicals in food ("food scares") in the media and take inappropriate action (Wilkinson, Rowe, & Lambert, 2004). Overreactions can also cause consequences at the public level. Toxicologists have pointed out that "ignorance of basic principles of dose-response … results in huge amounts of public money being misspent by focusing on reduction or elimination of many trivial, or even imaginary hazards" (Monro, 2001). Thus, enhancing consumers' chemical literacy by sensitizing them to the fact that "the dose makes the poison"[1] might be an approach for handling consumer reactions to food scares in the future. As women showed higher dose-response insensitivity than men, communication might focus particularly on women.

Second, our findings emphasize the importance of general attitudes toward chemicals and risk perceptions of synthetic chemicals in consumers' food choices. While using these attitudes to make food choices is generally a legitimate strategy, some consumers might have an overly simple view of foods with synthetic chemicals as dangerous, and thus giving inappropriate attention to synthetic contents of food products. Future communication about chemicals in food could be targeted at shifting consumer attitudes away from the "synthetic equals dangerous" perception to the more appropriate perception that all foods consist of chemicals, and all chemicals may be dangerous when ingested in large amounts. If consumers with strongly negative attitudes toward chemicals no longer equated synthetic with toxic and natural with safe, consumers would be able to judge food hazards more appropriately.

4.4 Limitations and Future Research

We were able to explain 45% of the preference for natural food, which highlights that influences other than attitudes toward chemicals and risk perceptions play a role in the preference for natural food. Thus, we propose that in future research the strength of the influence of chemical attitudes on the preference for natural food be compared to the influence of other factors such as universalism, personality traits and food involvement. Furthermore, we suggest that the role of consumer dose-response insensitivity and its effects on risk perception be investigated in other contexts inside and outside food, regarding different synthetic and natural food ingredients, or synthetic chemicals in other consumer products such as cosmetics or children's toys. Additionally, future research might further investigate the distinction between optimistic and pessimistic attitudes regarding chemicals. Researchers have shown that consumer pessimism about food safety is affected by food safety incidents, while optimism is not changed through such incidents (de Jonge, 2008). It

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[1] This frequently used quote originates from Paracelsus, whose exact words were "It depends only upon the dose whether a poison is poison or not." (Jacobi, 1951, p. 95)

would be interesting to examine whether such dynamics also apply to attitudes toward chemicals.

References

Branen, A. L., Davidson, P. M., Salminen, S., & Thorgate III, J. H. (2002). *Food Additives* (2nd ed.). New York, NY: Marcel Dekker.

Bundesamt für Gesundheit. (2007). Faktenblatt Zusatzstoffe. Retrieved from http://www.bag.admin.ch/themen/lebensmittel/04861/04974/index.html?lang=de

Bundesforschungsinstitut für Ernährung und Lebensmittel. (2008). *Nationale Verzehrsstudie II, Ergebnisbericht, Teil 1*. Karlsruhe, Germany: Author. Retrieved from http://www.was-esse-ich.de/uploads/media/NVS_II_Abschlussbericht_Teil_1_mit_Ergaenzungsbericht.pdf

Byrne, B. (2001). *Structural equation modeling with AMOS, basic concepts, applications, and programming*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1997). Beyond bipolar conceptualizations and measures: the case of attitudes and evaluative space. *Personality and Social Psychology Review, 1*(1), 3-25.

Conner, M., & Sparks, P. (2002). Ambivalence and attitudes. *European Review of Social Psychology, 12*, 37-70.

Davidson, D. J., & Freudenburg, W. R. (1996). Gender and environmental risk concerns - A review and analysis of available research. *Environment and Behavior, 28*(3), 302-339.

de Boer, J., Hoogland, C. T., & Boersema, J. J. (2007). Towards more sustainable food choices: Value priorities and motivational orientations. *Food Quality and Preference, 18*(7), 985-996.

de Jonge, J. (2008). *A monitor for consumer confidence in the safety of food.* PhD Thesis, Wageningen University, Wageningen, Netherlands.

Devcich, D. A., Pedersen, I. K., & Petrie, K. J. (2007). You eat what you are: Modern health worries and the acceptance of natural and synthetic additives in functional foods. *Appetite, 48*(3), 333-337.

Dickson-Spillmann, M., Siegrist, M., Keller, C., & Wormuth, M. (2009). Phthalate exposure through food and consumers' risk perception of chemicals in food. *Risk Analysis, 29*(8), 1170-1181.

Dimitri, C., & Greene, C. (2002). Recent growth patterns in the U.S. organic foods market. *Agriculture Information Bulletin, 777*, 1-39.

Dosman, D. M., Adamowicz, W. L., & Hrudey, S. E. (2001). Socioeconomic determinants of health- and food safety-related risk perceptions. *Risk Analysis, 21*(2), 307-317.

Dreezens, E., Martijn, C., Tenbult, P., Kok, G., & de Vries, N. K. (2005a). Food and the relation between values and attitude characteristics. *Appetite, 45*(1), 40-46.

Dreezens, E., Martijn, C., Tenbult, P., Kok, G., & de Vries, N. K. (2005b). Food and values: an examination of values underlying attitudes toward genetically modified- and organically grown food products. *Appetite, 44*(1), 115-122.

Eertmans, A., Victoir, A., Vansant, G., & Van den Bergh, O. (2005). Food-related personality traits, food choice motives and food intake: Mediator and moderator relationships. *Food Quality and Preference, 16*(8), 714-726.

European Commission. (2001). Fact sheet on dioxin in feed and food. Retrieved from http://ec.europa.eu/dgs/health_consumer/library/press/press170_en.pdf

European Commission. (2004). *Special Eurobarometer: Attitudes of European citizens towards the environment* (217/ Wave 62.1). Retrieved from http://ec.europa.eu/public_opinion/archives/ebs/ebs_295_en.pdf

European Commission. (2006). *Special Eurobarometer: Health and food* (246- Wave 64.3.). Retrieved from http://ec.europa.eu/health/ph_publication/eb_food_en.pdf
European Commission. (2008). *Special Eurobarometer: Attitudes of European citizens towards the environment* (295/ Wave 68.2). Retrieved from http://ec.europa.eu/public_opinion/archives/ebs/ebs_295_en.pdf
European Economic Community. (2000). Directive 2000/13/EC of the European Parliament and of the Council of 20 March 2000 on the approximation of the laws of the Member States relating to the labelling, presentation and advertising of foodstuffs. *Official Journal of the European Community L 109, p. 29 of 29.9.2000.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:109:0029:0042:EN:PDF.
Grankvist, G., & Biel, A. (2001). The importance of beliefs and purchase criteria in the choice of eco-labeled food products. *Journal of Environmental Psychology, 21*(4), 405-410.
Grankvist, G., & Biel, A. (2007). Predictors of purchase of eco-labeled food products: A panel study. *Food Quality and Preference, 18*(4), 701-708.
Hamm, U., Gronefeld, F., & Halpin, D. (2002). Analyse des europäischen Lebensmittelmarktes für Bioprodukte. Retrieved from http://orgprints.org/1066/1/omiard-hamm-et-al-2002-summary.pdf
Jacobi, J. (1951). *Paracelsus: Selected writings*. New York, NY: Pantheon.
Knight, A., & Warland, R. (2004). The relationship between sociodernographics and concern about food safety issues. *Journal of Consumer Affairs, 38*(1), 107-120.
Kraus, N., Malmfors, T., & Slovic, P. (2001). Intuitive toxicology: Expert and lay judgments of chemical risks. In P. Slovic (Ed.), *The perception of risk* (pp. 285-315). London, England: Earthscan Publications.
Lockie, S., Lyons, K., Lawrence, G., & Grice, J. (2004). Choosing organics: a path analysis of factors underlying the selection of organic food among Australian consumers. *Appetite*, *43*(2), 135-146.
MacGregor, D. G., Slovic, P., & Malmfors, T. (1999). "How exposed is exposed enough?" Lay inferences about chemical exposure. *Risk Analysis, 19*(4), 649-659.
Magnusson, M. K., Arvola, A., Hursti, U. K. K., Aberg, L., & Sjoden, P. O. (2003). Choice of organic foods is related to perceived consequences for human health and to environmentally friendly behaviour. *Appetite, 40*(2), 109-117.
Miles, S., Brennan, M., Kuznesof, S., Ness, M., Ritson, C., & Frewer, L. J. (2004). Public worry about specific food safety issues. *British Food Journal, 106*(1), 9-22.
Monro, A. M. (2001). Toxicologists -- come out and educate! *Trends in Pharmacological Sciences, 22*(6), 325-327.
Poortinga, W., & Pidgeon, N. F. (2003). Exploring the dimensionality of trust in risk regulation. *Risk Analysis, 23*(5), 961-972.
Raats, M. M., & Shepherd, R. (1996). Developing a subject-derived terminology to describe perceptions of chemicals in foods. *Risk Analysis, 16*(2), 133-146.
Roininen, K., Lahteenmaki, L., & Tuorila, H. (1999). Quantification of consumer attitudes to health and hedonic characteristics of foods. *Appetite, 33*(1), 71-88.
Rozin, P. (2005). The meaning of "natural" - Process more important than content. *Psychological Science, 16*(8), 652-658.
Rozin, P. (2006). Naturalness judgments by lay Americans: Process dominates content in judgments of food or water acceptability and naturalness. *Judgment and Decision Making Journal*, *1*(2), 91-97.

Rozin, P., Ashmore, M., & Markwith, M. (1996). Lay American conceptions of nutrition: Dose insensitivity, categorical thinking, contagion, and the monotonic mind. *Health Psychology, 15*(6), 438-447.

Rozin, P., & Fallon, A. E. (1987). A perspective on disgust. *Psychological Review, 94*(1), 23-41.

Rozin, P., Spranca, M., Krieger, Z., Neuhaus, R., Surillo, D., Swerdlin, A., & Wood, K. (2004). Preference for natural: instrumental and ideational/moral motivations, and the contrast between foods and medicines. *Appetite, 43*(2), 147-154.

Schifferstein, H. N. J., & Ophuis, P. A. M. O. (1998). Health-related determinants of organic food consumption in the Netherlands. *Food Quality and Preference, 9*(3), 119-133.

Schwartz, S. H., Melech, G., Lehmann, A., Burgess, S., Harris, M., & Owens, V. (2001). Extending the cross-cultural validity of the theory of basic human values with a different method of measurement. *Journal of Cross-Cultural Psychology, 32*(5), 519-542.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*(2), 195-203.

Siegrist, M., Keller, C., & Kiers, H. A. L. (2006). Lay people's perception of food hazards: Comparing aggregated data and individual data. *Appetite, 47*(3), 324-332.

Slovic, P. (2001). Trust, emotion, sex, politics and science: surveying the risk-assessment battlefield. In P. Slovic (Ed.), *The perception of risk* (pp. 390-412). London, England: Earthscan Publications.

Sparks, P., & Shepherd, R. (1994). Public perceptions of the potential hazards associated with food-production and food-consumption - an empirical study. *Risk Analysis, 14*(5), 799-806.

von Alvensleben, R. (2001). Beliefs associated with food production methods. In L. J. Frewer, E. Risvik & H. Schifferstein (Eds.), *Food, People and Society*. Berlin, Heidelberg: Springer.

Wilkinson, S., Rowe, G., & Lambert, N. (2004). The risks of eating and drinking. *EMBO reports, 5*(special issue), 527-531.

Chapter IV

Development and Validation of a Short, Consumer-Oriented Nutrition Knowledge Questionnaire

Abstract

A short scale was developed and validated that assesses consumers' knowledge about nutrition. Sixty-four nutrition knowledge items were derived from consumer interviews and expert recommendations about healthy eating. Items were administered as a postal survey to a sample of consumers randomly drawn from the directory (response rate = 37%, *N* = 1,043). Twenty items were retained to build the final nutrition knowledge scale. Internal reliability, criterion and construct validity were acceptable. Associations of the scale with self-reported food consumption frequencies indicated limited correlation of nutrition knowledge with food choice. Widespread nutrition knowledge gaps in consumers were revealed.

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1 Introduction

The role of nutrition knowledge in dietary behaviour is ambiguous. Increasing nutrition knowledge appears to be an efficient intervention to change diet behaviour of target groups such as obese and overweight mothers (Klohe-Lehman et al., 2006) and low-literacy adults (Howard-Pitney, Winkleby, Albright, Bruce, & Fortmann, 1997), and higher nutrition knowledge scores were associated with higher intake of fruit and vegetables (De Vriendt, Matthys, Verbeke, Pynaert, & De Henauw, 2009). Meanwhile, numerous studies have identified weak associations between nutrition knowledge and food intake in the general population (Sapp & Jensen, 1997; Shepherd & Towler, 1992; Wardle, Parmenter, & Waller, 2000). Different explanations have been provided for this weak relationship.

Firstly, food choices are not influenced by nutrition knowledge alone. There is a large range of other influences. Time constraints, the sensory appeal of food, cost, an individual's mood or family traditions also play a role in food choices. Socio-demographic characteristics, vegetarianism, attitudes towards the environment or risk perceptions e.g. regarding pesticide residues represent further influences (review in Pollard, Kirk, & Cade, 2002; Steptoe, Pollard, & Wardle, 1995). Environmental cues (often unknowingly) influence consumers' food choices, including the presence of fast-food restaurants, stockpiling of foods or the layout of dining tables (Sobal & Wansink, 2007; Wansink, 2004).

Secondly, a methodological shortcoming present in nutrition knowledge instruments for the general population might have led to attenuated associations with behaviour. Many questionnaires focused on declarative knowledge about nutrition (Miller & Achterberg, 2000) which is factual knowledge, such as "oily fish contains polyunsaturated fatty acids". Measures of declarative nutrition knowledge often used scientific terms that lay respondents might be unfamiliar with. For example, laypeople were asked to tick the type of oil which contains mostly monounsaturated fat among coconut oil, sunflower oil, etc. (Parmenter & Wardle, 1999a) or respondents had to tick the ten foods in a list which were highest in protein content (Shepherd & Towler, 1992). Such assessments might have underestimated laypeople's knowledge and led to limited relationships with dietary behaviour. In contrast to declarative nutrition knowledge, procedural nutrition knowledge is knowledge of skills and strategies (Anderson, 1995). It is knowing how to do something, such as how to compose a healthy menu. Therefore, procedural nutrition knowledge might be more closely related to diet behaviour than declarative nutrition knowledge.

In this paper, we describe the development and validation of a new scale that assesses nutrition knowledge. Our aim was to create a short scale that is based on consumers' natural language of food. We wanted to include items referring to consumers' everyday cognitions about the healthfulness of diet. The scale should encompass both declarative and procedural nutrition knowledge. We aimed to validate the scale by comparing it to an established nutrition knowledge questionnaire and by evaluating consumer subgroups expected to perform differently. We assessed the relationships between the scale and consumers' self-reported food consumption to evaluate its power in predicting behaviour. Because our scale was developed on the basis of proximity to consumers, we expected higher relationships between nutrition knowledge and food consumption than observed in previous research.

2 Methods

2.1 Development

We used two approaches for item generation. The first source of items was a series of interviews. Eleven Swiss consumers of both genders and various age groups and backgrounds were interviewed about food and health. Consumers were asked which foods they considered especially healthy or unhealthy and why, and they were asked about the overall composition of a healthy diet. Items were generated based on those statements that were considered to be most closely related to behaviour. The second source of items was recommendations by Swiss nutrition experts. These included the food pyramid (Walter, Infanger, & Mühlemann, 2007), a series of leaflets about different food groups (e.g. meat, dairy, oils, sweets) (Swiss Society for Nutrition, 2009), and leaflets about healthier alternatives to popular but unhealthy foods (e.g. ham vs. bacon) (Swiss Society for Nutrition, 2007).

We tried to reflect consumers' language of food by only using terms that consumers had used in the interviews, such as calories, vitamins, minerals. Care was taken in item generation to avoid scientific names of nutrients that were not used by the interviewees, i.e. saturated fatty acids or starches. Healthfulness of foods was expressed in terms of healthy or by referring to calories.

The final set of items included declarative nutrition knowledge questions on calorie and nutrient contents (e.g. "The same amount of sugar and fat contains equally many calories") and food comparisons (e.g. "A salad dressing made with mayonnaise is as healthy as the same dressing made with mustard"); and procedural nutrition knowledge questions on the relative contribution of different food groups to a healthy nutrition (e.g. "For healthy nutrition, dairy products should be consumed in the same amounts as fruit and vegetables"), on the role of fat (e.g. "Fat is always bad for your health; you should therefore avoid it as much as possible") and on the benefit of fruit and vegetable consumption (e.g. "To eat healthily, you should eat less fat. Whether you also eat more fruit and vegetables does not matter").

2.2 Content and Face Validity

For content validity the questions were reviewed by two food scientists of the ETH Zurich. Following these reviews, some items regarded as inappropriate by the experts were removed from the questionnaire, other items were re-formulated for enhanced precision and clarity. The remaining questionnaire contained 64 items. To ensure face validity in a pre-test respondents (N = 6) were explicitly asked to comment on the items, particularly to judge whether the items covered their nutrition knowledge. Only few comments were made which did not require item changes or deletions.

2.3 Survey and Participants

The questionnaire was mailed to a random sample of 3,000 households in the German-speaking part of Switzerland. Addresses were automatically selected from the telephone directory. The household member over 18 years whose birthday was next was asked to fill out the questionnaire within two weeks. Two reminders were sent out to non-responders. There were 136 invalid addresses due to relocation or death. A response rate of 37% (N = 1,053) was achieved. Ten respondents were excluded as they showed non-random missing patterns in the nutrition knowledge questionnaires. The mean age was 52.9 (SD = 16.4) years, for further sample descriptions see Table 4.1.

Table 4.1: Gender, Education, Nutrition or Health-Related Qualifications, BMI, Origin and Food-Related Routines of the Survey Sample (*N* = 1043)

	n	%
Female	623	60
Last finished school		
Primary	42	4
Lower secondary school	62	6
Upper secondary vocational school	493	48
Upper secondary university preparation school	173	17
University	266	26
Nutrition or health-related qualifications	140	14
BMI categories		
Underweight (BMI < 18.5)	33	3
Normal weight (18.5 to 24.9)	615	60
Overweight (25.0 to 29.9)	314	30
Obese class I (30.0 to 39.9)	65	6
Obese class II (≥ 40.0)	5	1
Swiss origin	902	89
Vegetarians or vegans	34	3
Food providers in their household	729	70

Note. *N* may slightly vary due to missing demographic data.

2.4 Scale Construction

For scale construction and evaluation in terms of reliability and validity, correct responses were scored as one, while incorrect responses, don't know-answers or blanks were scored as zero; analyses when cases with blanks were deleted yielded virtually the same results. Item analyses were undertaken to construct the final nutrition knowledge scale with a view to discarding items that were answered correctly by less than 20% or more than 80% of respondents and items with item-total correlations below .2 (Parmenter & Wardle, 2000).

2.5 Reliability, Criterion and Construct Validity

Internal reliability was assessed using Cronbach's alpha (α). To measure criterion validity, respondents also had to fill in the General Nutrition Knowledge questionnaire (GNKQ) by Parmenter and Wardle (1999a). We only included the three subscales awareness of dietary recommendations, food sources of nutrients, and dietary choices. We used a translated German version of the GNKQ (Keller, 2009) and we evaluated the questionnaire according to the instructions provided by the authors (Parmenter & Wardle, 1999b).

To evaluate construct validity, performance between different subgroups was compared (Parmenter & Wardle, 2000). Respondents with health- and nutrition-related qualifications were expected to perform higher than those without such qualifications, and higher performance was expected from women compared to men.

2.6 Relationship Between the Nutrition Knowledge Scale and Behaviour

We used a food frequency questionnaire (FFQ) as a proxy of behaviour. The FFQ contained 40 food and drink items. The items were chosen on the basis of expert recommendations on healthy alternatives to typically eaten unhealthy foods (Swiss Society for Nutrition, 2007), and on the basis of existing food frequency questionnaires (Hearty, McCarthy, Kearney, & Gibney, 2007; Hu et al., 1999). Portion sizes were given for each food item. Consumers were asked to indicate their consumption frequency using nine categories ranging from *6 or more per day* to *1-3 a month* and *rarer*. For further analysis, these categories were coded as numbers 1 to 9; the higher the number, the more frequent the consumption. Missing values for food items were imputed via the Expectation-Maximisation algorithm for respondents with up to three missing values for food variables and up to two missing values for drink variables. Food and drink consumption variables were used as predictors. Following imputation, no variable had more than 1.5% missings.

3 Results

The final nutrition scale included 20 items (Table 4.2). Cronbach's alpha for the scale was $\alpha = .73$. Three items that were answered correctly by slightly more than 80% of respondents were retained because their content was considered particularly interesting; one item with an item-total correlation < .2 was retained for the same reason.

Table 4.2: The 20 Items of the Nutrition Knowledge Scale, Their Correct Answer, Their Discrimination Index and the Percentage of Respondents Answering Correctly (*N* = 1043). Data are Sorted in Descending Order of Correct Response Rates.

	True/false	Discrimination index	% correct responses
Lentils contain only few useful nutrients, therefore their health benefit is not great.	F	.36	83
If you have eaten high-fat foods, you can reverse the effects by eating apples.	F	.34	83
If cream is whipped it contains less calories than in its liquid form.	F	.40	83
A healthy meal should consist of half meat, a quarter vegetables and a quarter side dishes.	F	.36	78
Fat contains fewer calories than the same amount of fibre.	F	.36	75
A salad dressing made with mayonnaise is as healthy as the same dressing made with mustard.	F	.24	74
Fat is always bad for your health; you should therefore avoid it as much as possible.	F	.32	71
Pasta with tomato sauce is healthier than pasta with mushroom and cream sauce.	T	.21	71
A balanced diet implies eating all foods in the same amounts.	F	.34	67
The health benefit of fruit and vegetables lies alone in the supply of vitamins and minerals.	F	.36	62
Bacon contains more calories than ham.	T	.22	62

	True/false	Discrimination index	% correct responses
Oily fish (salmon, mackerel) contain healthier fats than red meat.	T	.19	61
To eat healthily, you should eat less fat. Whether you also eat more fruit and vegetables does not matter.	F	.29	60
A scoop of chocolate ice-cream is just as healthy as a scoop of lemon sorbet.	F	.30	60
The same amount of beef steak and chicken breast contains equally many calories.	F	.29	59
The same amount of sugar and fat contains equally many calories.	F	.32	54
A sandwich with mozzarella contains as many calories as the same sandwich with Gruyere cheese.	F	.20	54
For a healthy nutrition, dairy products should be consumed in the same amounts as fruit and vegetables.	F	.31	53
Skimmed milk contains fewer minerals than full-fat milk.	F	.22	52
Brown sugar is much healthier than white sugar.	F	.25	36

We calculated the sum of points for each respondent. In the following, the nutrition knowledge scale will be referred to as the Consumer Nutrition Knowledge scale (CoNKS).

The correlation of the GNKQ total score with the CoNKS was $r = .67$ ($p < .001$). This size of correlation indicates that the two tests largely measure the same construct. The overall mean of CoNKS scores was 13.0 ($SD = 3.7$, $Min = 0$, $Max = 20$). The distribution of CoNKS scores was slightly negatively skewed, which could be expected as all consumers tend to have at least some nutrition knowledge.

Tests of mean differences showed that respondents who reported having nutrition or health-related qualifications ($M = 14.6$, $SD = 3.1$) scored higher at the CoNKS than those without such qualifications ($M = 12.7$, $SD = 3.7$) (t (205.5) = 6.4, $p < .001$). Women ($M = 13.3$, $SD = 3.6$) had slightly higher nutrition knowledge than men ($M = 12.4$, $SD = 3.8$) (t (1034) = 3.8, $p < .001$). Further, there was a negative correlation between nutrition knowledge and age ($r = -.23$, $p < .001$). Education correlated positively with nutrition knowledge ($r = .18$, $p < .001$).

The correlations of the CoNKS and the GNKQ with food consumption are shown in Table 4.3. Highest correlations of the CoNKS with food consumption were observed with vegetable, fruit and water consumption. The CoNKS performed similarly to the GNKQ in predicting food consumption, although correlations with the GNKQ tended to be slightly higher.

Table 4.3: Pearson's Correlations of the CoNKS and the GNKQ With Food and Drink Consumption (Only Foods With at Least One Correlation at $p < .01$ Shown). Data are Sorted in Descending Order of Correlations Between Food Consumption and the CoNKS Scale.

	CoNKS	GNKQ
Vegetables (cup)	.28**	.27**
Water (cup)	.19**	.23**
Fruit (piece)	.19**	.22**
Sausages (sausage)	-.18**	-.22**
Sodas (cup)	-.17**	-.23**
Cereal (cup)	.15**	.20**
Egg-based pasta (plate)	-.15**	-.22**
Chips, croquettes (cup)	-.13**	-.22**
Green salad (plate)	.11**	.09**
Fish, shellfish (cup)	.11**	.16**
Wholemeal bread (slice)	.10**	.13**
Crisps (cup)	-.10**	-.15**
Lentils (cup)	.09**	.10**
Red meat (cup)	-.09**	-.08**
Margarine (tablespoon)	-.09**	-.13**
Processed meats (slice)	-.08**	-.15**
White bread (slice)	-.08*	-.11**

** $p < .01$
* $p < .05$

4 Discussion

The CoNKS showed good internal reliability. Validity of the CoNKS was confirmed via correlations with the GNKQ through subgroup differences. Respondents with health- and nutrition-related qualifications scored better at the CoNKS than respondents without such qualifications. Thus, the CoNKS was able to distinguish between health-and-nutrition-literate and lay respondents. The difference between literate and lay respondents might have been higher if the type of qualification had been further specified and the literate sample selected more appropriately. Associations of the CoNKS with gender and other demographic variables were in line with previous research (Parmenter, Waller, & Wardle, 2000).

Contrary to our expectations, the correlations of the CoNKS with food and drink consumption were not much higher than those observed in previous studies. By ensuring proximity to the consumers, we tried to create a scale that would give consumers a chance to show their nutrition knowledge (rather than their lack of knowledge), particularly those unfamiliar with scientific nutrition terms. The fact that correlations with behaviour were still rather low supports the previous finding that the relationships between nutrition knowledge and consumption behaviour are indeed weak, which is probably due to the influence of other factors on behaviour including situational and environmental characteristics. Correlations of our scale with fruit, vegetable and water consumption tended to be higher than correlations with consumption of less healthy foods, which has been observed previously (De Vriendt, et al., 2009; Wardle, et al., 2000). Thus, it appears that better nutrition knowledge primarily leads to increased consumption of healthy foods, while effects on consumption of unhealthy foods are weaker. The CoNKS performed similarly to the GNKQ in correlations with food consumption, which indicates that general nutrition knowledge can be assessed with a fraction of the items in the GNKQ.

The CoNKS revealed some widespread knowledge gaps in Swiss consumers. Nearly 40% of consumers saw the health benefit of fruit and vegetables in the supply of vitamins and minerals alone. It thus appears that consumers are not aware of the beneficial nutrient composition of fruit and vegetables, which includes energy through carbohydrates, fibre and water. Around 40% of respondents were not aware of the different fats in oily fish and red meat, and of the difference between lean and fatty cuts of meat. Thus, sensitization of consumers toward different types and cuts of meat and their healthfulness is needed. Another focus of nutrition education should be the overall composition of a healthy diet. Nearly half of all consumers thought dairy products should be consumed in the same amounts as fruit and vegetables, and 33% of consumers believed that all food groups should be eaten in the same amounts for a healthy diet.

Some limitations of the present study should be addressed. First, the socio-demographic characteristics of our sample are not completely in line with census data of the Swiss adult general population (Bundesamt für Statistik, 2009). Sixty percent of our respondents were female, while in the Swiss general adult population, there are only 51% females. The average age of our sample (53 years) was five years above that of the population (48 years). Finally, in our sample there were fewer individuals who finished their education after nine years of mandatory schooling (10% vs.15%), and fewer university graduates (26% vs. 33%) than in the general population, but more people with intermediate degrees (65% vs. 52%).

The correct response to most knowledge items was false. The initial 64-item questionnaire unintentionally contained more items to be answered with false, and most true-items happened not to fulfil the statistical criteria for inclusion in the final scale. Finally, it could be argued on the basis of high rates of correct answers that some of the items are oversimplifying and that items are too easy. It was our aim, however, to create a scale close to consumers' everyday food cognitions and choices, a scale that does not underestimate consumers' knowledge by using scientific terms. Thus, above-average performance could be expected.

Nutrition knowledge is dynamic. As knowledge about diet and health is expanding, dietary recommendations are updated, replaced or removed. For instance, the American dietary reference intakes (DRIs) for vitamins have continuously changed since their first appearance in 1968 (Council for Responsible Nutrition, 2001). A more dramatic example is the ever-conflicting evidence on the link between dietary fat and health (Pollan, 2008). Therefore, nutrition knowledge scales like the CoNKS may be applicable for a certain period before they need to be revised.

A valuable approach to further validate the CoNKS scale might be to use other assessments of diet behaviour than FFQs. These are liable to bias through under- and over-reporting, particularly in certain demographic groups (Kristal, Feng, Coates, Oberman, & George, 1997). An experimental approach involving real food choices, weighed records or food diaries might provide food consumption data that is closer to effective consumption (Bingham et al., 1995).

The CoNKS can be used in future studies as a short but comprehensive instrument. The CoNKS and the GNKQ both measure overall nutrition knowledge. The CoNKS consists of 20 items, the GNKQ of 89 items. Therefore, the CoNKS is a very economical instrument for measuring nutrition knowledge in larger consumer groups.

As associations between nutrition knowledge and diet behaviour –assessed by FFQs- have repeatedly been shown to be weak, we recommend that nutrition campaigns aimed at increasing fruit and vegetable consumption take into account other factors of food choice. These include, for example, time constraints, family traditions or sensory appeal. The convenience of consuming an apple as a snack, the memory of the family eating fresh cherries from the garden, or the sweet taste of fruit should not be neglected in favor of pure nutrition education.

References

Anderson, J. R. (1995). *Cognitive psychology and its implications* (4th ed.). New York, NY: W. H. Freeman and Company.

Bingham, S. A., Cassidy, A., Cole, T. J., Welch, A., Runswick, S. A., Black, A. E., . . . Day, N. E. (1995). Validation of weighed records and other methods of dietary assessment using the 24-H urine nitrogen technique and other biological markers. *British Journal of Nutrition, 73*(4), 531-550.

Bundesamt für Statistik. (2009). *Statistisches Lexikon der Schweiz (ESPOP).* Neuchâtel, Switzerland: Author. Retrieved from http://www.bfs.admin.ch/bfs/portal/de/index/infothek/lexikon/bienvenue___login/blank/zugang_lexikon.open.html

Council for Responsible Nutrition. (2001). Vitamins: Historical comparison of RDIs, RDAs and DRIs, 1968 to present, from http://www.crnusa.org/about_recs3.html

De Vriendt, T., Matthys, C., Verbeke, W., Pynaert, I., & De Henauw, S. (2009). Determinants of nutrition knowledge in young and middle-aged Belgian women and the association with their dietary behaviour. *Appetite, 52*(3), 788-792.

Hearty, Á. P., McCarthy, S. N., Kearney, J. M., & Gibney, M. J. (2007). Relationship between attitudes towards healthy eating and dietary behaviour, lifestyle and demographic factors in a representative sample of Irish adults *Appetite, 48*(1), 1-11.

Howard-Pitney, B., Winkleby, M. A., Albright, C. L., Bruce, B., & Fortmann, S. P. (1997). The Stanford Nutrition Action Program: A dietary fat intervention for low-literacy adults. *American Journal of Public Health, 87*(12), 1971-1976.

Hu, F. B., Rimm, E., Smith-Warner, S. A., Feskanich, D., Stampfer, M. J., Ascherio, A., . . . Willett, W. C. (1999). Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. *American Journal of Clinical Nutrition, 69*, 243-249.

Keller, C. (2009). Differences in nutrition knowledge, food affect, health and taste attitude and risk perception between four dietary patterns among Swiss adults. *Unpublished Manuscript*.

Klohe-Lehman, D. M., Freeland-Graves, J., Anderson, E. R., McDowell, T., Clarke, K. K., Hanss-Nuss, H., . . . Milani, T. J. (2006). Nutrition knowledge is associated with greater weight loss in obese and overweight low-income mothers. *Journal of the American Dietetic Association, 106*(1), 65-75.

Kristal, A. R., Feng, Z. D., Coates, R. J., Oberman, A., & George, V. (1997). Associations of race/ethnicity, education, and dietary intervention with the validity and reliability of a food frequency questionnaire - The women's health trial feasibility study in minority populations. *American Journal of Epidemiology, 146*(10), 856-869.

Miller, C. K., & Achterberg, C. L. (2000). Reliability and validity of a nutrition and food-label knowledge test for women with type 2 diabetes mellitus. *Journal of Nutrition Education, 32*(1), 43-48.

Parmenter, K., Waller, J., & Wardle, J. (2000). Demographic variation in nutrition knowledge in England. *Health Education Research, 15*(2), 163-174.

Parmenter, K., & Wardle, J. (1999a). Development of a general nutrition knowledge questionnaire for adults. *European Journal of Clinical Nutrition, 53*(4), 298-308.

Parmenter, K., & Wardle, J. (1999b). Scoring information on the general nutrition knowledge questionnaire, from http://www.ucl.ac.uk/hbrc/diet/resources.html

Parmenter, K., & Wardle, J. (2000). Evaluation and design of nutrition knowledge measures. *Journal of Nutrition Education, 32*(5), 269-277.

Pollan, M. (2008). *In defence of food. The myth of nutrition and the pleasures of eating*. London, England: Penguin.

Pollard, J., Kirk, S. F. L., & Cade, J. E. (2002). Factors affecting food choice in relation to fruit and vegetable intake: a review. *Nutrition Research Reviews, 15*(2), 373-387.
Sapp, S. G., & Jensen, H. H. (1997). Reliability and validity of nutrition knowledge and diet-health awareness tests developed from the 1989-1991 diet and health knowledge surveys. *Journal of Nutrition Education, 29*(2), 63-72.
Shepherd, R., & Towler, G. (1992). Nutrition knowledge, attitudes and fat intake - application of the theory of reasoned action. *Journal of Human Nutrition and Dietetics, 5*(6), 387-397.
Sobal, J., & Wansink, B. (2007). Kitchenscapes, tablescapes, platescapes, and foodscapes - Influences of microscale built environments on food intake. *Environment and Behavior, 39*(1), 124-142.
Steptoe, A., Pollard, T. M., & Wardle, J. (1995). Development of a measure of the motives underlying the selection of food - the Food Choice Questionnaire. *Appetite, 25*(3), 267-284.
Swiss Society for Nutrition. (2007). Merkblatt "Auswahl fettarmer Lebensmittel", from http://www.sge-ssn.ch/fileadmin/pdf/100-ernaehrungsthemen/40-lebensmittel/6-oel_fett_nuesse/Merkblatt_Auswahl_fettarmer_Nahrungsmittel.pdf
Swiss Society for Nutrition. (2009). Ernährungsinfos Lebensmittel, from http://www.sge-ssn.ch/de/ernaehrungsinfos/lebensmittel.html
Walter, P., Infanger, E., & Mühlemann, P. (2007). Food Pyramid of the Swiss Society for Nutrition. *Annals of Nutrition and Metabolism, 51 (suppl 2)*, 15-20.
Wansink, B. (2004). Environmental factors that increase the food intake and consumption volume of unknowing consumers. *Annual Review of Nutrition, 24*, 455-479.
Wardle, J., Parmenter, K., & Waller, J. (2000). Nutrition knowledge and food intake. *Appetite, 34*(3), 269-275.

Chapter V

Consumers’ Knowledge of Healthy Diets and its Correlation With Dietary Behaviour

Abstract

Background: Procedural nutrition knowledge is knowledge of how to eat a healthy diet. This type of knowledge potentially plays an important role in dietary behaviour. Previous studies of consumers' nutrition knowledge did not systematically assess procedural nutrition knowledge. Thus, we administered a survey of procedural nutrition knowledge to Swiss consumers to assess the prevalence of misconceptions about healthy eating.

Methods: We developed 13 procedural nutrition knowledge items. Nine items were based on qualitative consumer interviews and four items were derived from expert guidelines. The items had a true/false format. We administered the items to a random population sample in a written postal survey (N = 1,043). The survey also assessed the consumers' self-reported food consumption. For each respondent, we computed the number of correctly answered knowledge items and we correlated this number with food consumption frequencies.

Results: The procedural nutrition knowledge items received between 3% and 38% incorrect answers. Individuals with a higher number of correctly answered items consumed more vegetables (r = .29). Higher knowledge was associated with the female gender, younger age, higher education, nutrition-related qualifications and not being on a diet ($p < .001$).

Conclusions: Our findings indicate that misconceptions exist in the general population about healthy eating. These misconceptions are associated with a decreased consumption of foods usually defined as healthy. Some population sub-groups seem particularly susceptible to holding such misconceptions. The implications for nutrition education, particularly concerning the role of fruit and vegetable consumption as well as the food pyramid are discussed.

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1 Introduction

Knowledge is not a unified structure, but consists of various components. Ryle (1949, pp. 27-32) first described two knowledge components, one representing "knowing that" and the other, "knowing how". In cognitive psychology, these notions have been extended into the concepts of declarative and procedural knowledge. Declarative knowledge is defined as knowledge about facts and things, while procedural knowledge is knowledge about the way in which actions are performed (Anderson, 1995). Therefore, procedural knowledge is closer to behaviour than declarative knowledge. This distinction between declarative and procedural knowledge has also more recently been applied to the field of nutrition knowledge (Miller & Achterberg, 2000; Worsley, 2002). In this regard, declarative nutrition knowledge includes, for example, knowledge of the fibre content of fruit and the number of calories in full fat milk. Examples of procedural knowledge include knowing how to choose the healthier of two snacks or how to compose a balanced menu.

Many measures of nutrition knowledge have been described to date. Some of these have assessed declarative knowledge (Buttriss, 1997; Gracey, Stanley, Burke, Corti, & Beilin, 1996; McKernan Boulanger, Pérez-Escamilla, Himmelgreen, Segura-Millán, & Haldeman, 2002), while others have included questions regarding procedural knowledge, usually in the form of food choices (e.g. "Which of the following snacks is the healthiest: apple, snack bar, yoghurt?") or by asking the question "Do dieticians recommend eating more, less or the same amount of fruit, fats, fibre?" (Barratt, 2001; Dallongeville, Marecaux, Cottel, Bingham, & Amouyel, 2001; Hawkes & Nowak, 1998; Klohe-Lehman et al., 2006; Kolodinsky, Harvey-Berino, Berlin, Johnson, & Reynolds, 2007; Miller & Achterberg, 2000; Parmenter & Wardle, 1999; Towler & Shepherd, 1990; Whati et al., 2005). Most nutrition knowledge measures have been designed for and applied to subpopulations such as cardiac patients (Hawkes & Nowak, 1998), adolescents (Whati, et al., 2005) or middle-aged men (Dallongeville, et al., 2001). To our knowledge, no study has investigated procedural nutrition knowledge in the general population, despite the recognition that it is the how to that is particularly difficult and should be given greater attention (Worsley, 2002).

We conducted a survey that assessed Swiss consumers' procedural nutrition knowledge. We evaluated knowledge in terms of the divergence between the consumers' ideas about how to follow a healthy diet and the experts' guidelines (US Department of Health and Human Services and Department of Agriculture, 2005; Walter, Infanger, & Mühlemann, 2007; World Health Organization, 2003). These expert guidelines incorporated aspects such as the food pyramid, the concept of a balanced diet, the role of fat reduction and the need to increase fruit and vegetable consumption. Our intention was to assess the prevalence of misconceptions regarding how to follow a healthy diet and to relate these misconceptions to dietary behaviour. We aimed to identify issues which could potentially be included in nutrition education programmes.

2 Materials and Methods

2.1 Development of Procedural Nutrition Knowledge Items

The main source of knowledge items was a series of qualitative, semi-structured interviews about nutrition and health conducted with Swiss consumers (N = 11). The interviews explored the consumers' definitions of healthy eating as well as the strategies and principles illustrating what they understood a healthy eating pattern to be. The interviews were conducted between March and May 2008. The interview questions followed a funnel design protocol; first, the interviewer asked open questions such as "What are your priorities when buying food?" or "Which potential health benefit do you expect from your nutrition?" The questions then became increasingly specific, for example, "Please describe a healthy diet" or "How often should you eat vegetables to gain a health benefit?" We identified a number of discrepancies between the interviewees' responses and the experts' recommendations for healthy eating from which we created nine knowledge items. Further, we rephrased four expert statements about the Swiss food pyramid (Walter, et al., 2007) to become knowledge items.

Content validity describes whether the items are representative of the area under study (Coolican, 1999). To confirm content validity, two nutrition experts from the ETH Zurich reviewed our generated items and intended responses. Following expert reviews and some modifications, we checked face validity through a pre-test of the items in a small consumer sample (N = 6). Face validity refers to how relevant the items appear to be to the respondents (Parmenter & Wardle, 2000). In our context, we assessed face validity by asking the pre-test respondents whether they felt that the items represented their nutrition knowledge. Their comments did not require any item changes or deletions. The possible responses to the items were true, false or don't know.

As a proxy for consumers' dietary behaviour, we developed a food frequency questionnaire (FFQ) containing 40 food and beverage items. We chose those items on the basis of expert recommendations on healthy alternatives to typically consumed unhealthy foods (Schweizerische Gesellschaft für Ernährung, 2007) and existing food frequency questionnaires (Hearty, McCarthy, Kearney, & Gibney, 2007; Hu et al., 1999). We provided nine response categories to indicate the consumption frequency of each food, ranging from 6 or more per day to 1–3 a month and rarer. We provided habitual portion sizes for each item, except for nine items where we indicated a standard portion size of two decilitres.

2.2 Survey

We administered the procedural nutrition knowledge items and the FFQ to a sample of the general Swiss population in the context of a broader written nutrition survey. This was a postal survey which was conducted between January and March 2009. Three thousand households in the German-speaking part of Switzerland were randomly chosen from the telephone directory. The household member over 18 years of age whose birthday was closest to the date the questionnaire was received was asked to fill out the survey within two weeks. Non-respondents received two reminders. The survey was accompanied by a letter and a prepaid return envelope. The number of respondents in the final sample was N = 1,043, which represents a response rate of 36.4% (after 136 invalid addresses were excluded). The mean (± SD) age was 53 years (± 16), and 60% of the respondents (n = 623) were female.

We did not seek ethical approval for the survey, as our study design complied with the American Psychological Association's (APA's) guidelines (2002).

2.3 Data Processing and Statistical Analysis

The procedural nutrition knowledge items were randomly embedded in a 64-item nutrition knowledge assessment within the survey. While the correct answer to one-quarter of all 64 items was true, the correct answer to all procedural nutrition knowledge items was false. Correct (i.e. *false*) responses were scored as 3, don't know answers were scored as 2 and incorrect (*true*) responses were scored as 1. This scoring pattern was guided by the rationale that the awareness that one does not know is superior to simply having incorrect knowledge.

We calculated the percentage of correct responses for every item and computed the sum of the 13 items for each respondent. This sum value served to analyse the mean differences between various respondent groups through *t*-tests and to measure the associations with self-reported food consumption frequencies through rank correlations. We excluded the cases with missing values in procedural nutrition knowledge items from the analyses.

We coded the food frequency data by the numbers 1 (*rarer than 1–3 per month*) to 9 (*6 or more per day*). To replace the missing values in the food frequency data, we used the expectation-maximisation (EM) algorithm. The EM algorithm is an iterative process based on maximum likelihood for imputing missing values (Coolican, 1999). We applied the algorithm to variables with up to three missing values for food variables and up to two missing values for drink variables. All food and drink consumption variables were used as predictors. Following the imputation, no variable had more than 1.5% missing data. $p < 0.01$ was considered statistically significant. Data analysis was performed using PASW Statistics 17.0 (SPSS Inc.).

3 Results

3.1 Internal Reliability and Item-Total Correlations

Cronbach's alpha is a statistic for estimating the internal consistency (i.e. reliability) of a scale. It varies between 0 and 1; the higher the value, the higher the reliability (Coolican, 1999; Field, 2005). The 13-item procedural nutrition knowledge scale had a Cronbach's alpha of .70, indicating acceptable reliability. The correlations between the items and the total score ranged between .19 and .44, indicating that the items were able to discriminate between high- and low-scoring respondents.

3.2 Response Frequencies

Table 5.1 reports the response frequencies for the knowledge items. For seven items, more than 80% of respondents gave the correct answer (i.e., indicated false statements). Half to three-quarters of the participants gave the correct answer to the other six items. Thus, some of these items evoked relatively high rates of incorrect responses. Every third consumer believed that for a healthy diet, dairy products should be consumed in the same amounts as fruit and vegetables, while every fifth consumer believed that a healthy meal should consist of half meat and one quarter vegetables and side dishes. Nearly one-third of the consumers thought that a balanced diet implied eating all foods in the same amounts, and over 17% of the consumers thought that eating a diet with a high proportion of fruit and vegetables was as unbalanced as eating a diet high in fat. More than one quarter of the consumers agreed that fat was always bad for one's health, and 38% showed a focus on fat reduction that was coupled with a lack of awareness about the need to simultaneously increase fruit and vegetable consumption. This was indicated by agreement with item 12. Don't know rates were generally low, apart from items 7 and 13, which received approximately 12% of such answers. Thus, the consumers were rarely in doubt about their knowledge.

Table 5.1: Ranking of Response Rates to 13 Procedural Nutrition Knowledge Questions (*N* = 1036-1043)

Item Number	Procedural nutrition knowledge question	Response %			Source
		False	True	Don't know	
1	Fruit can be fully replaced by vitamin and mineral supplements.	91.8	4.1	4.0	Int
2	A healthy diet means nothing other than eating vitamins.	88.0	10.2	1.8	Int
3	If crisps did not contain so much salt, you could eat more of them without any problem.	87.4	6.6	5.9	Int
4	To eat healthily, you should eat less. It does not matter what foods you reduce.	86.0	11.8	2.2	Int
5	Meat should be the basis of our daily diet.	85.4	12.9	1.6	Pyr
6	Instead of eating fruit you can drink fruit juice.	84.9	11.2	3.8	Pyr
7	If you have eaten high-fat foods, you can reverse the effects by eating apples.	82.9	3.0	14.1	Int
8	A diet with a high proportion of fruit and vegetables is just as unbalanced as a diet high in fat.	78.7	17.6	3.7	Int
9	A healthy meal should consist of half meat, a quarter vegetables and a quarter side dishes.	78.0	19.1	2.9	Pyr
10	Fat is always bad for your health; you should therefore avoid it as much as possible.	71.0	26.6	2.4	Int
11	A balanced diet implies eating all foods in the same amounts.	67.1	28.2	4.6	Int
12	To eat healthily, you should eat less fat. Whether you also eat more fruit and vegetables does not matter.	60.3	37.9	1.7	Int
13	For healthy nutrition, dairy products should be consumed in the same amounts as fruit and vegetables.	53.3	35.0	11.6	Pyr

Note. Questions are sorted in descending order of false response rates.
For this article, the questions were translated from German into English.
Int = Consumer interviews; Pyr = Swiss food pyramid

3.3 Relationships between procedural nutrition knowledge and dietary behaviour

Of the 40 calculated correlations between procedural nutrition knowledge and the reported frequencies of food intake, 15 correlations were significant at $p < .01$ (Table 5.2). Positive correlations indicated higher procedural nutrition knowledge and higher food consumption; negative correlations indicated higher knowledge and lower consumption. The highest correlations were with vegetable ($r = .29$), water ($r = .22$), sausage ($r = –.21$) and fruit ($r = .18$) consumption ($p < .01$).

Table 5.2: Spearman's Rank Correlations of Procedural Nutrition Knowledge Score with Food and Beverage Consumption Frequencies (N = 1002-1009)

Food item	*r*
Vegetables (cup)	.29
Water (cup)	.22
Sausages (sausage)	-.21
Fruit (piece)	.18
Cereal (cup)	.14
Egg-based pasta (plate)	-.15
Chips, croquettes (cup)	-.12
Red meat (cup)	-.13
Lentils (cup)	.11
Unsalted nuts (handful)	.11
Margarine (tablespoon)	-.11
Light sodas (cup)	.09
Boiled potatoes (cup)	-.09
Low-fat milk (cup)	-.09
Full-fat milk (cup)	-.08

Note. Only foods with a significant correlation at $p < .01$ shown.

3.4 Subgroup Differences in Procedural Nutrition Knowledge

Women (M = 34.5 ± 4.2) had higher procedural knowledge scores than men (M = 33.2 ± 4.6) ($t(1006) = 4.7$, $p < .001$). Furthermore, there was a significant negative association between age and procedural nutrition knowledge ($r = –.34$, $p < .001$). Higher education was correlated with higher procedural nutrition knowledge ($r = .28$, $p < .001$).

The consumers who reported having special health- or nutrition-related qualifications (M = 35.3 ± 4.0) scored higher on the knowledge scale than the consumers without such qualifications (M = 33.7 ± 4.5) ($t(1009) = 3.9$, $p < .001$). The consumers who reported following special diets prescribed by a doctor had significantly less procedural nutrition knowledge (M = 32.3 ± 5.1) than the consumers who were not following such diets (M = 34.2 ± 4.3) ($t(1008) = –4.4$, $p < .001$).

4 Discussion

This study intended to assess the procedural nutrition knowledge of Swiss consumers. All items evoked correct responses from the majority of the consumers, indicating that most consumers were well informed about how to follow a healthy eating pattern. Widespread correct knowledge was particularly observed in relation to the fact that a healthy diet means more than consuming vitamins and minerals.

For a substantial share of the items, however, every third to fifth participant was unable to answer correctly. The practical implications of these misconceptions were reflected in the self-reported consumption frequencies of various foods. For example, the consumers with lower procedural nutrition knowledge scores consumed fewer vegetables, less fruit and less water, but more sausages than consumers with higher knowledge scores.

The items assessed in our survey provided insight into consumers' understanding of key concepts related to healthy eating, such as the contribution of different food groups to a healthy diet, the term "balanced diet", the role of fat reduction, different types of fatty acids and the difference between a healthy diet and the consumption of vitamins.

The consumers' agreement with items 5, 9 and 13 highlights the fact that the food pyramid is not present in many consumers' minds and that it is not taken into account in daily food choices. According to the food pyramid, fruit and vegetables should constitute the largest part to our diet (five servings) after fluids, dairy should be consumed in smaller amounts (three servings) and meat should play an even more minor role (one serving) (Walter, et al., 2007). Some consumers believed that eating healthily meant eating less, no matter which foods were reduced (item 4). The literature, however, suggests that the way to maintain a zero energy balance is not primarily by eating less but by lowering the energy density of the diet (Rolls, Drewnowski, & Ledikwe, 2005). This can be accomplished by increasing the consumption of foods such as water-rich vegetables, fruit and cooked whole grains. Such a strategy reduces the risk of obesity and its associated disorders without leaving individuals feeling hungry and deprived (Rolls, et al., 2005). We conclude that efforts are needed to raise awareness of the food pyramid as well as the understanding that a healthy diet does not necessarily mean having to reduce portion sizes, but rather that the diet should be composed differently.

The respondents appeared to have difficulty interpreting the term "balanced diet" (items 8 and 11). In the literature, this is defined as a diet that contains the "essential nutrients in appropriate quantities required for growth or the maintenance of health approximately each day or over a period of a week" (Anderson, 2005). In practice, a balanced diet is one which is low in saturated and trans fats, cholesterol, added sugars, salt and alcohol and high in fruit and vegetables. While a misunderstanding of the term "balanced diet" can be blamed on a lack of consumer knowledge, it may also indicate a general problem with the term itself. Those who are not aware of the precise definition of this term are not able to interpret this term in the way it is intended using common sense.

Many consumers agreed that to eat healthily, less fat, but not necessarily more fruit and vegetables, should be eaten (item 12). Such a perception is not in line with dietary guidelines, which recommend limiting the energy intake from total fats while increasing the consumption of fruit and vegetables (e.g.,US Department of Health and Human Services and Department of Agriculture, 2005). The beneficial effects of the combination of increased fruit and vegetable consumption and lower saturated fatty acid intake on blood pressure were demonstrated in the Dietary Approaches to Stop Hypertension (DASH) trial (Appel, Moore, Obarzanek, Vollmer, & Svetkey, 1997; Harnden, Frayn, & Hodson, 2010).

The fact that some consumers thought that fats should be completely excluded from their diet (item 10) suggests that they are not aware of the different types of fatty acids. The consumption of polyunsaturated fatty acids is explicitly recommended in expert guidelines because they may reduce risk of coronary heart disease (Hu et al., 2002; Lavie, Milani, Mehra, & Ventura, 2009). Some respondents were unsure as to whether eating fat could be reversed by eating apples (item 7). While the moderate consumption of saturated fats is not problematic for health, it is not possible to reverse the effect of consumed fat by consuming fruit and vegetables.

Poor procedural knowledge was observed in those consumers who thought that a healthy diet was equivalent to consuming vitamins (item 2). This idea does not grasp the complexity of healthy nutrition, which should include other nutrients (e.g., polyunsaturated fatty acids) and non-nutrients (e.g., fibre) in the appropriate amounts (Anderson, 2005). Focussing only on the consumption of vitamins is an oversimplification of the healthy nutrition concept. Our recommendation with regard to this finding is that consumers should stay focussed on the overall composition of food intake and on the inclusion of a large number of different foods to cover all nutrients.

Some consumers thought that fruit could be replaced entirely by fruit juice or tablets (items 1 and 6). Although nutrition guidelines allow replacing one fruit a day with a glass of fruit juice, the remaining fruit should be consumed in its original form because of the low dietary fibre and higher sugar content in juice (Steptoe et al., 2003; Walter, et al., 2007). The WHO treats fruit and vegetables as a food category rather than referring to their nutrients, because the benefits of fruit and vegetables cannot be ascribed to one or several particular nutrients (World Health Organization, 2003). That they put forward the idea of replacing fruit with tablets suggests that consumers are not aware of the overall beneficial composition of fruit which, besides vitamins and minerals, includes carbohydrates, water, fibre and secondary plant constituents.

In Switzerland and other European countries, nutrition campaigns have been undertaken which aimed at increasing the population's dietary quality. The most prominent of these is the 5-a-day campaign (www.5amtag.ch, www.5aday.nhs.uk). At the same time, numerous additional intervention programmes have been designed to improve the nutrition knowledge and practice of particular target groups such as immigrants (www.migesplus.ch), consumers at risk of developing diabetes (www.actiond.ch) or children (www.suissebalance.ch). Our findings highlight areas in which this ongoing nutrition education should be reinforced or supplemented.

Associations between demographic variables (e.g. gender, education) and nutrition knowledge replicate earlier findings (Parmenter, Waller, & Wardle, 2000). We found a negative relationship between age and nutrition knowledge, indicating lower knowledge in older individuals. This might be because many of our items were based on the food pyramid, which only appeared in 1998 in Switzerland (Walter, et al., 2007). Thus, older respondents might be less familiar with the food pyramid, suggesting that future nutrition campaigns should focus on the elderly.

The respondents who reported following nutrition guidelines prescribed by a doctor showed lower knowledge than the respondents not following such guidelines. This suggests that patients are not properly informed about dietary recommendations by their general practitioner (GP), or that such information is not effective. Possible reasons for this are poor nutrition knowledge or a lack of education skills among GPs (Cadman & Wiles, 2003; Duff & Livingstone, 1997), or GPs' view that dietary education is outside their role (Pomeroy & Worsley, 2009).

Most of the correlations detected between procedural nutrition knowledge and food consumption were small according to Cohen's definition (1992). This arguably limits the substantiveness of our findings. Our correlations, however, fell into the range of the correlations reported in other studies (Sapp & Jensen, 1997; Shepherd & Towler, 1992; Wardle, Parmenter, & Waller, 2000). Small or medium correlations, when considered from the population-wide perspective, may add up to a significant impact on public health (Wardle, et al., 2000). The most likely explanation for the limited correlations is the influence of factors other than knowledge on food consumption, such as time constraints, sensory appeal, price, mood, family traditions or socio-demographic factors (Pollard, Kirk, & Cade, 2002; Steptoe, Pollard, & Wardle, 1995).

Our study has some limitations that need to be addressed. First, the validity of the procedural nutrition knowledge items might be compromised, as some items seemed to depend on subjective interpretation. However, we tried to maximise objectivity by having two nutrition experts review the items. The fact that the respondents with health or nutrition related qualifications had higher procedural nutrition knowledge scores also supports the validity of our items (Parmenter & Wardle, 2000).

Food consumption was assessed through an unvalidated, retrospective food frequency questionnaire. This might have led to distortions in self-reported consumption frequencies.

Another limitation is that an age and gender bias was observed in our sample compared to the Swiss census data, which report an average age of 48 years and a proportion of 51% females in the population (Bundesamt für Statistik, 2009).

5 Conclusion

Our survey shows generally good procedural nutrition knowledge in consumers whilst highlighting areas in which substantial numbers of consumers hold misconceptions. Many consumers seem unfamiliar with the practical implications of the food pyramid, the concept of a balanced diet and the importance of increasing fruit and vegetable consumption. Particularly older individuals and those following medically prescribed diets could profit from more education on how to compose a healthy diet. The challenge will be to find the right settings and effective ways to communicate nutrition messages to consumers.

References

American Psychological Association. (2002). Ethical principles of psychologists and code of conduct. Retrieved from http://www.apa.org/ethics/code2002.html

Anderson, J. J. B. (2005). *Nutrition and health: An introduction*. Durham, NC: Carolina Academic Press.

Anderson, J. R. (1995). *Cognitive psychology and its implications* (4th ed.). New York, NY: W. H. Freeman and Company.

Appel, L. J., Moore, T. J., Obarzanek, E., Vollmer, W. M., & Svetkey, L. P. (1997). A clinical trial of the effects of dietary patterns on blood pressure. *The New England Journal of Medicine, 336*(16), 1117-1124.

Barratt, J. (2001). Diet-related knowledge, beliefs and actions of health professionals compared with the general population: an investigation in a community Trust. *Journal of Human Nutrition and Dietetics, 14*(1), 25-32.

Bundesamt für Statistik. (2009). *Statistisches Lexikon der Schweiz (ESPOP)*. Neuchâtel, Switzerland: Author. Retrieved from http://www.bfs.admin.ch/bfs/portal/de/index/infothek/lexikon/bienvenue___login/blank/zugang_lexikon.open.html

Buttriss, J. L. (1997). Food and nutrition: Attitudes, beliefs, and knowledge in the United Kingdom. *American Journal of Clinical Nutrition, 65*, S1985-S1995.

Cadman, L., & Wiles, R. (2003). Nutrition advice in primary care: evaluation of practice nurse nutrition training programmes. *Journal of Human Nutrition and Dietetics, 9*(2), 147-156.

Cohen, J. (1992). Statistical power analysis. *Current Directions in Psychological Science, 1*(3), 98-101.

Coolican, H. (1999). *Research methods and statistics in psychology* (3rd ed.). London, England: Hodder & Stoughton Educational.

Dallongeville, J., Marecaux, N., Cottel, D., Bingham, A., & Amouyel, P. (2001). Association between nutrition knowledge and nutritional intake in middle-aged men from Northern France. *Public Health Nutrition, 4*(1), 27-33.

Duff, E. N., & Livingstone, M. B. E. (1997). A survey of nutrition knowledge, practice, attitudes and behaviour of general practitioner trainees in Ireland. *Journal of Human Nutrition and Dietetics, 10*, 219-228.

Field, A. (2005). *Discovering statistics using SPSS*. London, England: SAGE Publications.

Gracey, D., Stanley, N., Burke, V., Corti, B., & Beilin, L. J. (1996). Nutritional knowledge, beliefs and behaviours in teenage school students. *Health Education Research, 11*(2), 187-204.

Harnden, K. E., Frayn, K. N., & Hodson, L. (2010). Dietary Approaches to Stop Hypertension (DASH) diet: applicability and acceptability to a UK population. *Journal of Human Nutrition and Dietetics, 23*(1), 3-10.

Hawkes, A., & Nowak, M. (1998). A validated nutrition knowledge questionnaire for cardiac patients. *Australian Journal of Nutrition and Dietetics 55*, 21-24.

Hearty, Á. P., McCarthy, S. N., Kearney, J. M., & Gibney, M. J. (2007). Relationship between attitudes towards healthy eating and dietary behaviour, lifestyle and demographic factors in a representative sample of Irish adults *Appetite, 48*(1), 1-11.

Hu, F. B., Bronner, L., Willett, W. C., Stampfer, M. J., Rexrode, K. M., Albert, C. M., . . . Manson, J. E. (2002). Fish and omega-3 fatty acid intake and risk of coronary heart

disease in women. *Jama-Journal of the American Medical Association, 287*(14), 1815-1821.
Hu, F. B., Rimm, E., Smith-Warner, S. A., Feskanich, D., Stampfer, M. J., Ascherio, A., . . . Willett, W. C. (1999). Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. *American Journal of Clinical Nutrition, 69*, 243-249.
Klohe-Lehman, D. M., Freeland-Graves, J., Anderson, E. R., McDowell, T., Clarke, K. K., Hanss-Nuss, H., . . . Milani, T. J. (2006). Nutrition knowledge is associated with greater weight loss in obese and overweight low-income mothers. *Journal of the American Dietetic Association, 106*(1), 65-75.
Kolodinsky, J., Harvey-Berino, J. R., Berlin, L., Johnson, R. K., & Reynolds, T. W. (2007). Knowledge of current dietary guidelines and food choice by college students: Better eaters have higher knowledge of dietary guidance. *Journal of the American Dietetic Association, 107*(8), 1409-1413.
Lavie, C. J., Milani, R. V., Mehra, M. R., & Ventura, H. O. (2009). Omega-3 Polyunsaturated Fatty Acids and Cardiovascular Diseases. *Journal of the American College of Cardiology, 54*(7), 585-594.
McKernan Boulanger, P., Pérez-Escamilla, R., Himmelgreen, D., Segura-Millán, S., & Haldeman, L. (2002). Determinants of nutrition knowledge among low-income, Latino caretakers in Hartford, Conn. *Journal of the American Dietetic Association, 102*(7), 978-981.
Miller, C. K., & Achterberg, C. L. (2000). Reliability and validity of a nutrition and food-label knowledge test for women with type 2 diabetes mellitus. *Journal of Nutrition Education, 32*(1), 43-48.
Parmenter, K., Waller, J., & Wardle, J. (2000). Demographic variation in nutrition knowledge in England. *Health Education Research, 15*(2), 163-174.
Parmenter, K., & Wardle, J. (1999). Development of a general nutrition knowledge questionnaire for adults. *European Journal of Clinical Nutrition, 53*(4), 298-308.
Parmenter, K., & Wardle, J. (2000). Evaluation and design of nutrition knowledge measures. *Journal of Nutrition Education, 32*(5), 269-277.
Pollard, J., Kirk, S. F. L., & Cade, J. E. (2002). Factors affecting food choice in relation to fruit and vegetable intake: a review. *Nutrition Research Reviews, 15*(2), 373-387.
Pomeroy, S. E., & Worsley, A. (2009). Enhancing the dietary management of general practice patients through collaborative care: perspectives of general practitioners and dietitians. *Nutrition & Dietetics, 66*(2), 81-86.
Rolls, B. J., Drewnowski, A., & Ledikwe, J. H. (2005). Changing the energy density of the diet as a strategy for weight management. *Journal of the American Dietetic Association, 105*, S98-S103.
Ryle, G. (1949). *The concept of mind* (2002 ed.). Chicago, IL: New University of Chicago Press.
Sapp, S. G., & Jensen, H. H. (1997). Reliability and validity of nutrition knowledge and diet-health awareness tests developed from the 1989-1991 diet and health knowledge surveys. *Journal of Nutrition Education, 29*(2), 63-72.
Schweizerische Gesellschaft für Ernährung. (2007). Auswahl fettarmer Nahrungsmittel. Retrieved from http://www.sge-ssn.ch/de/ernaehrungsinfos/inhaltsstoffe/fette.html
Shepherd, R., & Towler, G. (1992). Nutrition knowledge, attitudes and fat intake - application of the theory of reasoned action. *Journal of Human Nutrition and Dietetics, 5*(6), 387-397.
Steptoe, A., Perkins-Porras, L., McKay, C., Rink, E., Hilton, S., & Cappuccio, F. P. (2003). Behavioural counselling to increase consumption of fruit and vegetables in low income adults: randomised trial. *British Medical Journal, 326*, 855-861.

Steptoe, A., Pollard, T. M., & Wardle, J. (1995). Development of a measure of the motives underlying the selection of food - the Food Choice Questionnaire. *Appetite, 25*(3), 267-284.

Towler, G., & Shepherd, R. (1990). Development of a nutritional knowledge questionnaire. *Journal of Human Nutrition and Dietetics, 3*, 255-264.

US Department of Health and Human Services and Department of Agriculture. (2005). Dietary guidelines for Americans. Retrieved from http://www.health.gov/DietaryGuidelines/dga2005/document/default.htm

Walter, P., Infanger, E., & Mühlemann, P. (2007). Food Pyramid of the Swiss Society for Nutrition. *Annals of Nutrition and Metabolism, 51 (suppl 2)*, 15-20.

Wardle, J., Parmenter, K., & Waller, J. (2000). Nutrition knowledge and food intake. *Appetite*, *34*(3), 269-275.

Whati, L. H., Senekal, M., Steyn, N. P., Nel, J. H., Lombard, C., & Norris, S. (2005). Development of a reliable and valid nutritional knowledge questionnaire for urban South African adolescents. *Nutrition, 21*(1), 76-85.

World Health Organization. (2003). *Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation* (Technical report series, No. 916). Geneva, Switzerland: Author.

Worsley, A. (2002). Nutrition knowledge and food consumption: can nutrition knowledge change food behaviour? *Asia Pacific Journal of Clinical Nutrition, 11*, S579-S585.

Chapter VI

Consumer Perceptions of Food Safety – Implications for Hazard Communication

Abstract

Introduction: Many consumers are worried about the safety of their daily diet. Synthetic chemicals such as pesticides and colourings are subject to widespread health concerns. Experts, in contrast, see the major food-related health risk in the overconsumption of calories. Tailored risk communication could help consumers assess food risks more appropriately and take informed decisions regarding their food consumption. To be effective, such communication needs to take into account the factors that shape consumers' risk perceptions. The aims of this study were to quantify the influence of such potential factors on food risk perception and to assess the relationship between risk perception and behaviour.

Methods: A written survey in a random consumer sample was conducted in Switzerland (N = 1,200). The survey assessed consumers' risk perception of food ingredients with varying hazardousness. The assessment of potential influences on risk perception included technical knowledge about calories, pesticides, additives and bacteria, beliefs about chemicals, trust and other variables. Self-reported food purchase and consumption habits were also examined.

Results: The influence of various factors on risk perception differed according to the food risk, e.g. trust played a role in the risk perception of additives but not in the perception of other hazards. Knowledge also played a variable role. Consumers' risk perceptions were related to behaviour, e.g. higher risk perceptions of bacteria involved higher hygienic behaviour.

Discussion: Food risk communication needs to be adapted to the specific hazard in question. Enhancing consumers' technical knowledge about a hazard is not sufficient to change risk perceptions. Consumers' attitudes and beliefs also need to be taken into account. If risk perceptions are changed successfully, behaviour may also change.

Poster (Figure 6.1) presented as: Dickson-Spillmann, M. & Siegrist, M. *Consumers' perception of food safety – Implications for hazard communication.* 2010 EFFoST Annual Conference. Food and Health. Dublin, 10-12 November 2010.

Figure 6.1: Poster presented at the 2010 EFFoST Annual Conference, Dublin, 2010.

CONSUMERS‘ PERCEPTIONS OF FOOD SAFETY – IMPLICATIONS FOR HAZARD COMMUNICATION

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Introduction

- Differences between experts and consumers in food hazard perception (consumers: synthetic chemicals; experts: calories)
- Empirically: Ambiguous role of objective knowledge in consumers' food hazard perception → Importance of other factors?
- No existing knowledge tests regarding additives, pesticides, bacteria & mold in food
- Unclear relationships between consumers' food hazard perception and behaviour

Aim

- Evaluate influence of knowledge, attitudes and beliefs on hazard perception of bacteria & mold, pesticides, additives, calories
- Assess correlations between hazard perception and behaviour
- Identify consumers' knowledge gaps
- Derive implications for hazard communication

Method

- Construct knowledge questionnaires based on consumer (*N* = 11) and expert interviews (N = 11), consumer information sheets
- Borrow and construct attitude and beliefs scales: Perceived control, trust in producers and communicators, perceived subjective knowledge, perceived benefits of food technology, readiness to make long-term health efforts, perceived links between diet and health
- Postal survey (*N* = 1200; 40%; German-speaking population of CH)
- Knowledge test and attitude scales evaluation; reliability analyses ($\alpha \geq .70$); computation of scale scores
- Multiple regression analyses with hazard perception as dependent variable; bivariate correlations between hazard perception and behaviour; knowledge test response frequencies

Results

Significant predictors ($p<.05$) of food hazard perception

- Bacteria & mold ($R^2 = .09$):
  - \+ Readiness to make long-term health efforts
  - – Food technology benefits
- Pesticides ($R^2 = .13$):
  - \+ Trust in communication and control
  - – Food technology benefits, Objective knowledge
- Additives ($R^2 = .27$)
  - \+ Subjective knowledge, Perceived vague diet-health links
  - – Food technology benefits, Trust in producers and vendors, Perceived control, Objective knowledge
- Calories ($R^2 = .26$):
  - \+ Subjective knowledge, Readiness to make long-term health efforts, Perceived vague diet-health links
  - – Food technology benefits, Perceived control

Note. Predictors of hazard perception not listed were non-significant.

Results (cont.)

Correlations of food hazard perception with self-reported behaviour ($p<.01$)

- Bacteria & mold:
  - \+ Hygienic behaviour in domestic kitchen, Washing fruit and vegetables before consumption
- Pesticides:
  - \+ Washing fruit and vegetables before consumption
- Additives:
  - \+ Buying organic fruit and vegetables, paying attention to E-numbers on food packaging
- Calories:
  - \+ Fruit and vegetable consumption
  - – Sausage, white bread, chocolate bars, chips and sweet drinks consumption

Knowledge test response rates to selected items

Item	T/F	% correct responses
After cutting meat, to remove bacteria it is sufficient to wash the cutting board with warm water.	F	73
Foods always first spoil outside and then inside.	F	45
Residues of multiple pesticides on foods indicate inadequate use.	F	18
Pesticides lower the nutrient content of fruit and vegetables.	F	49
Organic foods do not contain additives.	F	41
Many additives have not been tested for their safety.	F	36
The same amount of sugar and fat contains equally many calories.	F	53
For a healthy nutrition, dairy products should be consumed in the same amounts as fruit and vegetables.	F	48

Discussion and Implications

- Objective knowledge lowers hazard perception of additives and pesticides in food → Consumer education may attenuate reactions to media reports («food scares»)
- The assessed factors explain more variance in hazard perception of additives and calories than in bacteria & mold and pesticides → Importance of other factors in consumers' hazard perception
- Attitudes and beliefs (e.g. trust) are related to perception of additives besides objective knowledge → Take into account when educating consumers
- Hazard perceptions are related to respective behaviours
- Widespread knowledge gaps particularly about healthy eating and safety aspects of food additives → Need for consumer education




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Chapter VII

Consumers’ Knowledge and Perception of Food Additives

Abstract

Purpose: Food additives, such as preservatives or emulsifiers, are seen by consumers as a medium health risk. To date, the role of objective knowledge, attitudes and beliefs in consumers' risk perception of food additives is unknown. Our first aim was to create a scale to assess consumers' objective knowledge about food additives. Our second aim was to evaluate the influence of objective knowledge on risk perception of synthetic food additives against other factors. These factors included trust, perceived negative health outcomes from diet, perception of benefits from food technology and general attitudes toward chemicals. We further assessed relationships between risk perception and additive avoidance behaviour.

Methods: We developed a knowledge test about food additives with 16 true/false items. The knowledge items, together with scales assessing risk perception, trust and other factors were administered to a random population sample in a written postal survey (N = 1,200).

Findings: The knowledge items received up to 54% incorrect responses. Lowest correct response rates were found on items regarding the legal, labelling and safety aspects of food additives. Trust in the producers and vendors of food products and perceived adverse health outcomes had the strongest negative influence on the risk perception of food additives, followed by objective knowledge. The other factors played a weaker, but significant role in risk perception. Higher risk perception implied avoiding food products with E-numbers.

Implications and value: Many consumers hold misconceptions about food additives. To be efficient, consumer information about food additives has to overcome barriers; most of all, consumers' distrust in financial stakeholders. Our findings are relevant to authorities who support consumers in making informed decisions about their food choices.

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1 Introduction

In Europe, for many consumers, food is primarily associated with taste and pleasure (European Commission, 2006). These positive associations, however, are often undermined by worries about the healthfulness of our daily diet. This study focuses on food additives, which have been subject to consumer concerns for many years.

1.1 Additives in Food

Food additives are defined in the EU Community legislation as "any substance not normally consumed as a food in itself and not normally used as a characteristic ingredient of food whether or not it has nutritive value, the intentional addition of which to food for a technological purpose … results ... in it or its by-products becoming directly or indirectly a component of such foods" (European Economic Community, 1988). Additives have many different functions ranging from modifying organoleptic qualities, to improving nutritive value or enhancing consumer convenience (Sumner & Eifert, 2002). Some examples of additives are preservatives, colourings and flavour enhancers. Additives can be made of synthetic (e.g. E214 Ethylparaben) or natural (e.g. E967 Xylitol) materials.

Additives in food are highly regulated and controlled[1]. In Europe, the European Food Safety Agency (EFSA) is responsible for testing the safety of additives. Based on the recommendations made by EFSA, the European Parliament and Council issue directives regarding the use of food additives (European Economic Community, 1994a, 1994b, 1995). Substances that are not explicitly mentioned in these directives are banned. Each permitted additive is assigned an E-number. Additives present in a food product have to be declared on the food product label (European Community, 2008a; European Economic Community, 2000). In organic foods, all usage of additives is to be avoided as far as possible. Only substances obtained through physical separation processes, cooking processes and fermentation are permitted as additives (European Community, 2007, 2008b).

1.2 Consumers' Perception of Food Additives

In the 1980s, there was a strong public focus on additives following the publication of books that propagated them as having adverse effects on health, such as triggering hyperactive behaviour in children (Emerton & Choi, 2008). As a consequence, consumers avoided products containing E-numbers. A study in the UK showed that, ten years later, consumers' concerns about additives had decreased (Sparks & Shepherd, 1994). Additives were perceived as a risk of low severity. This change in perception was due to the switch from a focus on the content and ingredients in food in the 1980s to a focus on the healthfulness of the diet as a whole in the 1990s (Armitstead, 1998). Despite this progress, in 1997, consumers reading food labels focused on additives rather than on nutrient contents (Wandel, 1997). Thus, additives still occupied a prominent place in consumers' minds.

More recently, additives continue to receive moderate levels of concern. In 2006, consumers rated additives as a risk of low dread (Siegrist, Keller & Kiers, 2006). In the Eurobarometer,

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[1] This study was conducted in Switzerland, which is not an EU member state. The regulations regarding additives are largely the same in Switzerland as in the EU. Switzerland has its own positive list but accepts food products complying with EU regulations; E-numbers, labeling regulations and regulations for organic foods are the same as in the EU (Bio Suisse, 2001; Eidgenössisches Departement des Innern, 2007).

food additives ranged in the middle of the consumer worries scale (European Commission, 2006). In Holland, only a small proportion of consumers (6%) rated E-numbers to belong to the 5 most relevant of 18 food-related topics, but at the same time, consumers perceived more information about food additives to be urgent (van Dillen, Hiddink, Koelen, de Graaf, & van Woerkum, 2004). In a qualitative study, Hungarian consumers expressed negative feelings about food additives, particularly preservatives and colours, associating them with carcinogenic effects. Consumers seemed unaware of the rigorous allowance and control system dealing with food additives (Tarnavölgyi, 2003). Altogether, these studies show that although food additives are no longer the object of strong consumer concerns, they never seem to have achieved full acceptance.

1.3 Factors Influencing Risk Perception of Food Technology and Relationship to Behaviour

To identify potential determinants of consumers' risk perceptions of food additives, we can draw on previous findings regarding public perception of other food technologies. The first, and perhaps most obvious, factor to consider is knowledge, or expertise. The idea that knowledge about a hazard lowers risk perceptions originates from studies showing that experts perceived lower risks of environmental, technological and food hazards compared to laypeople (Kraus, Malmfors, & Slovic, 2001; Savadori et al., 2004; Siegrist, Keller, Kastenholz, Frey, & Wiek, 2007). Empirically, the role of knowledge in risk perception has been ambiguous. In a study investigating consumers' perception of several food hazards, a positive relationship between knowledge and risk perception was observed regarding pesticides. No relationships were observed regarding high fat diets, microbial risks and genetically manipulated organisms (Frewer, Shepherd, & Sparks, 1994). Knowledge played a weak role in risk perception of non-medical gene technology applications including food (Connor & Siegrist, 2010). Respondents who had knowledge of wood-based food additives evaluated them as better than respondents who had misconceptions about them (Stern, Haas, & Meixner, 2009). One reason for the inconsistent relationship between knowledge and food risk perception could be the different methods used to assess knowledge. Some studies assessed consumers' subjective knowledge, while others assessed objective knowledge. Subjective and objective knowledge influence consumers' perceptions in different ways. According to one study, objective knowledge was not related to acceptance of genetically modified food products, while subjective knowledge was a significant determinant of acceptance (House et al., 2004)

Another reason for the inconsistent relationship is that laypeople's risk perception is not only determined by knowledge but also by other, more affective factors. The first factor to take into account is social trust, which has a much-demonstrated negative influence on consumers' risk perception. Trust is particularly important when consumers have little knowledge (Siegrist & Cvetkovich, 2000). In the food context, trust has been shown to influence consumers' perceptions of artificial sweeteners (Siegrist, Cvetkovich, & Roth, 2000), gene technology (Connor & Siegrist, 2010; Costa-Font & Gil, 2009), pesticides (Saba & Messina, 2003; Williams & Hammitt, 2001) and nanotechnology (Siegrist, Cousin, Kastenholz, & Wiek, 2007).

Consumers' risk perceptions are also related to perceptions of benefit (Alhakami & Slovic, 1994). Technologies that were viewed as beneficial by consumers were associated with less risk than technologies viewed as not beneficial (Frewer, Howard, & Shepherd, 1998; Siegrist & Cvetkovich, 2000). The mechanism underlying this negative relationship is affect, which influences both perception of risk and benefit (Finucane, Alhakami, Slovic, & Johnson, 2000). This relationship has been observed in various studies referring to food perception (Gaskell et al., 2004; Saba & Messina, 2003; Williams & Hammitt, 2001).

The severity of the perceived consequences of exposure to a hazard is another factor of risk perception. The concept of Severity incorporates aspects such as dread, threat to future generations, widespread disastrous consequences or that a hazard is becoming more serious (Sparks & Shepherd, 1994). Connor and Siegrist (2010) found that people with higher expectations of negative health outcomes of non-medical applications of gene technology had higher risk and lower benefit perceptions.

Perceived risk influences consumers' behavioural decisions (Kahneman & Tversky, 1979). Consumers may stop or reduce consuming certain products, shift to similar products with less perceived risk, or, if they consider the perceived risk as tolerable, continue consuming the product (Roselius, 1971). Consumers with higher risk perceptions of industrially produced and processed foods and perceived benefits of organic foods reported, for example, higher organic food consumption (Lockie, Lyons, Lawrence, & Grice, 2004). Similarly, consumers who gave more importance to pesticides in food were more likely to purchase foods with organic labels (Epp, Michalsky, Banasiak, & Böl, 2010).

1.4 Aim

The first aim of this study is to investigate consumers' knowledge about food additives and to assess the prevalence of knowledge gaps. The second aim is to assess attitudes and beliefs that we suspect, based on the literature, to influence consumers' perception of synthetic food additives. Our intention was to quantify the influence of knowledge and attitudes on the perception of additives, and to compare the strengths of these different influences. We hypothesised that objective knowledge, trust, perceived benefits of food technology and positive attitudes towards chemicals would be negatively related to the risk perception of additives. We expected negative attitudes towards chemicals and higher perceived links between diet and adverse health outcomes to be positively correlated with the risk perception of additives. We had no hypothesis regarding the relationship between subjective knowledge about food additives and risk perception. We further aimed to evaluate the behavioural consequences of consumers' risk perception of food additives. The overall aim of our study was to gain information on factors to consider when informing consumers about food additives.

2 Method

2.1 Knowledge and Attitudes Survey

All variables used in the present study were assessed in the context of a broader survey about consumers' perceptions of various food hazards. The survey included an extensive demographic section. Households in the German-speaking part of Switzerland were randomly chosen from the telephone directory. The household member over 18 years of age whose birthday was closest to the date the questionnaire was received was asked to fill out the survey within two weeks. Non-respondents received two reminders. The survey was accompanied by a letter and a postage prepaid return envelope. The number of respondents in the final sample was N = 1,200, which represents a response rate of 40.0%.

There were 55.0% women (n = 649) in the sample. The mean age was 52.4 years (SD = 16.0). Most of the respondents were the main food buyers in their household (72.7%, n = 851).

Nearly half of the respondents (46.4%, n = 551) had performed an apprenticeship after finishing secondary school; 25.8% (n = 306) had a higher education degree—thus, our sample was well educated.

2.2 Development of the Food Additives Knowledge Scale

A knowledge scale about food additives was developed from multiple sources. Items referring to the substances that are used as food additives were developed from the current list of additives permitted in the EU. Other items were re-phrased from consumer information sheets issued by the Federal Office of Public Health (FOPH); these items referred to safety aspects of foods available in Switzerland and to the declaration of additives on food packaging. Other items were developed in cooperation with two experts on food additives; these items were based on their experiences with consumers' expressed concerns about food additives.

The introduction to the knowledge test read as follows: "Please indicate whether the following statements are true or false in your view. Please make your judgments relative to foods that are available in Switzerland". The items were either true or false; additionally, there was the option of responding "don't know". All knowledge items were reviewed by two experts. The knowledge scale was pre-tested in 20 consumers selected by convenience sampling. Preliminary analysis indicated satisfying item discrimination and overall reliability. The knowledge scale consisted of 18 items, 9 of which were false.

Following the survey, the knowledge items were analysed. Two items showed lower item-total correlations than .2; thus, they did not sufficiently distinguish between low and high-scoring respondents. They were excluded from the final scale. The remaining 16 items of the food additives knowledge scale showed item-total correlations between .22 and .49. Internal reliability of the scale was good (α = .78).

To score the knowledge items, the value 0 was conferred to incorrect given responses, "don't know" responses or blanks, and the value 1 was conferred to correct given responses. Each respondent received a total knowledge score representing the sum of item scores. Respondents with more than 50% missing values in knowledge questions were excluded from data analysis (n = 84, 7.0%).

2.3 Assessment of Attitudes and Beliefs

Various consumer attitudes and beliefs were assessed. These assessments were embedded in a survey section, which gathered consumers' perceptions of additives and other chemicals (i.e. pesticides, environmental chemicals) occurring in food. Therefore, the attitudes and beliefs scales did not refer to food additives specifically.

2.3.1 Trust

Trust in the bodies controlling, regulating and communicating chemical food risks was assessed. The five items referred to food producers, supermarkets, the FOPH, the food quality control authority and consumer magazines/TV programmes. Responses were given on Likert scales ranging from 1 (*no trust*) to 6 (*very high trust*). Factor analysis split the five items into two factors: the financial stakeholders (food producers and vendors) on one hand, and the regulators and communicators (FOPH, food quality control and consumer media) on the other hand. We labelled these factors as Trust 1 (stakeholders) and Trust 2 (regulators, communicators). The mean for each factor was computed for every respondent. Cronbach's alpha for Trust 1 was α = .73, and for Trust 2 α = .69.

2.3.2 Subjective Knowledge

Subjective knowledge of food additives was assessed via the question "How much do you know about additives in food?" The response options ranged from 1 (*little*) to 6 (*very much*).

2.3.3 Attitudes Towards Food Technology

Five items assessed consumers' attitudes towards the technological modification of foods. These items referred to perceived benefits (e.g. "Consumers benefit from adapting foods to their needs using technology") or perceived negative consequences (e.g. "Technologically modified foods often adversely affect our health"). Responses were assessed on Likert scales ranging from 1 (*don't agree at all*) to 6 (*completely agree*). The internal reliability of the Attitudes Towards Food Technology scale was $\alpha = .72$.

2.3.4 Positive and Negative Attitudes Towards Chemicals

Consumers' general beliefs about chemicals were examined by drawing on a previous study (Dickson-Spillmann, Siegrist, & Keller, 2011). In that study, two reliable scales representing positive and negative attitudes towards chemicals were constructed. Positive attitudes relate to not being worried about chemicals and perceiving benefits (e.g. "Chemicals play an important role for the advancement of society", "Our society has to deal with more important risks than chemical risks"); negative attitudes represent fears and avoidance tendencies (e.g. "I am scared of chemical substances and the risks associated with them", "I do everything I can to avoid contact with chemicals and chemical products in my daily life").

2.3.5 Perceived Links Between Diet and Health

The perceived links between diet and adverse health outcomes were measured using five items. These items represented illness symptoms that consumers often associated with chemicals in food. Evidence for these consumer associations came from a series of consumer interviews about diet and health (Dickson-Spillmann, 2008), from past media reports about health outcomes of food additives and from anecdotes available on the internet. Consumers were asked to rate the strength of the relationship between diet and neurodermitis, asthma, illnesses of the central nervous system (e.g. Alzheimer, Parkinson, multiple sclerosis or epilepsy), hyperactivity and ill-humour. Responses were given on scales ranging from 1 (*no relationship*) to 4 (*strong relationship*). Consumers had the option of responding "don't know this symptom". The internal reliability of this scale was .74.

2.4 Assessment of Risk Perception

Risk perception of food additives was assessed along with risk perception of other food ingredients and components (such as salmonella, dioxins or fungicides). Of 20 items, 4 referred to food additives (synthetic flavourings, colourings, flavour enhancers, preservatives). We only assessed perception of synthetic, as opposed to natural, additives because data from a survey in 2008 (Dickson-Spillmann & Siegrist, 2008) indicated that consumers perceived natural substances as very low risk compared to synthetic substances. The introduction to the risk perception questions read: "Foods available in Switzerland may contain the following ingredients and components. How high do you rate the health risk from these ingredients and components for Swiss consumers?" Responses were given on a Likert scale ranging from 1 (*no risk*) to 6 (*high risk*), with the option of responding "I don't know this ingredient". Cronbach's α was .87.

2.5 Assessment of Behaviour

Two assessments were used as proxies of behaviour. On one hand, the natural product interest scale from the Health and Taste Attitude questionnaires (Roininen, Lahteenmaki, & Tuorila, 1999) was included. The Natural Product Interest scale, consisting of six items, measures consumers' interest in consuming unprocessed foods, organic foods, and foods that do not contain synthetic chemicals. Responses were given on a 6-point Likert scale ranging from 1 (*don't agree at all*) to 6 (*completely agree*). For each respondent, a scale mean was computed. On the other hand, consumers were asked whether they paid attention to purchasing foods without any additives; the response format to this question was *yes* (coded as 1) or *no* (coded as 0).

2.6 Data Analysis

We evaluated each knowledge scale item in terms of correct, incorrect and "don't know" response frequencies. Associations between objective knowledge and demographic variables were examined using *t*-tests and Pearson's correlations. The same procedures were used to evaluate associations between risk perception and demographic variables.

Multiple regression analysis was performed to evaluate the influence of knowledge, attitudes and beliefs on the risk perception of food additives. The knowledge, attitude and beliefs scales were independent variables, and risk perception of food additives was the dependent variable.

To quantify the association between risk perception, natural product interest and consumer's attention to E-numbers on food products, Pearson's correlations were calculated.

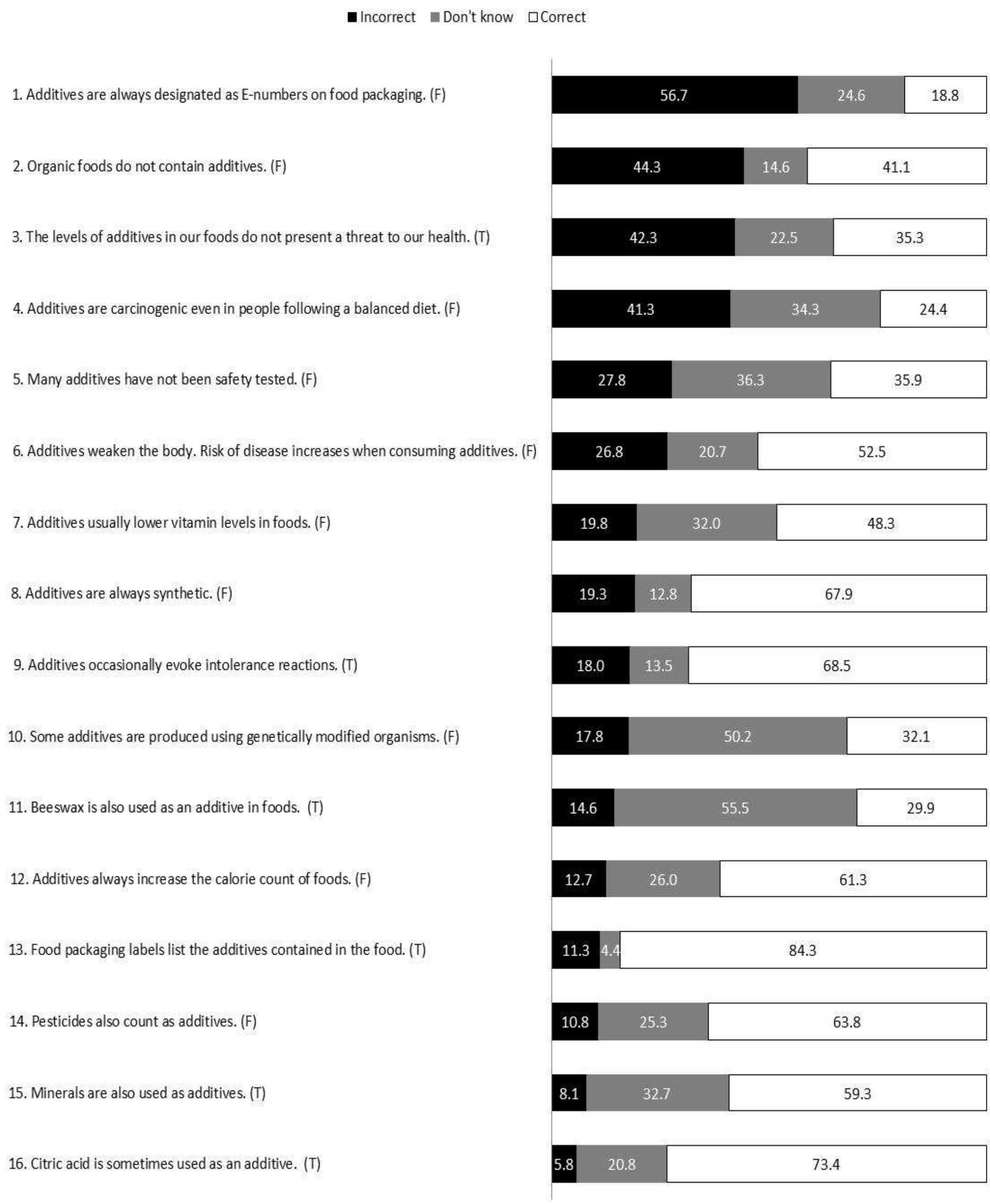
Results were considered significant if $p < .05$. Analyses were performed using PASW 17.0 (SPSS Inc.).

3 Results

3.1 Consumers' Knowledge of Additives and Correlation with Demographic Variables

Figure 7.1 shows the rates of correct, incorrect and "don't know" responses to the knowledge questions. The rates of incorrect responses ranged between 5.8% and 56.7%; thus, incorrect response rates were highly variable. The majority of participants thought that additives are always designated as E-numbers on food packaging. More than 40% thought that additives are carcinogenic in people following a balanced diet. In contrast, only 6-8% responded incorrectly to the questions regarding minerals and citric acid used as food additives. "Don't know" rates were higher than 20% for 12 questions; rates of more than 50% were found in relation to whether some additives are produced using genetically modified organisms and whether beeswax is used as a food additive. The mean knowledge score was 8.3 (SD = 3.4, Min = 0, Max = 16).

Figure 7.1: Response Rates to the Food Additive Knowledge Items, Sorted in Descending Order of Incorrect Responses (N = 1116)



There was a small correlation between food additive knowledge and education level (r = .15, p < .05). No difference in knowledge of food additives was found between men (M = 8.5, SD = 3.5) and women (M = 8.2, SD = 3.2; t(1147) = 2.1, p > .05), and knowledge of food additives did not correlate with age (r = .06, p > .05).

3.2 Comparing the Influence of Knowledge and Attitudes on Risk Perception of Food Additives

The mean risk perception of food additives was M = 3.5 (SD = 1.2). Men and women did not differ in their risk perception (t(1118) = -1.7, p > .05), and risk perception neither correlated with age (r = .01) nor with education (r = -.02) or with the number of children living in the household (r = .01, p > .05).

Table 7.1 shows the intercorrelations among the hypothesised predictors and risk perception. All correlations were significant at p <.01. Positive and negative correlations were in line with our hypotheses: with increasing trust, higher knowledge, higher perceived benefits of food technology and more positive attitudes towards chemicals, risk perception of food additives decreased; with stronger perceived links between diet and adverse health effects and higher negative attitudes about chemicals, risk perception of food additives increased. Subjective knowledge showed a positive correlation with risk perception.

Table 7.1: Bivariate Correlations Between Risk Perception of Food Additives and Potential Predictor Variables (N = 1099-1171)

	1	2	3	4	5	6	7	8	9
1. Risk perception	-	-.29*	-.15*	.29*	-.29*	.29*	-.21*	.14*	-.30*
2. Trust 1		-	.42*	-.05	.28*	-.13*	.05	-.03	.23*
3. Trust 2			-	.02	-.12*	.04	-.02	-.01	-.04
4. Diet-health links				-	-.19*	.24*	-.15*	.13*	-.21*
5. Positive attitudes					-	-.34*	.12*	-.06	.46*
6. Negative attitudes						-	-.15*	.14*	-.43*
7. Objective knowledge							-	.24*	.22*
8. Subjective knowledge								-	-.06
9. Food technology									-

Note. Positive and negative attitudes refer to attitudes towards chemicals.
*p<.05

Multiple regression analysis revealed a significant influence of all predictors on risk perception of food additives (Table 7.2). The variables Trust 1 and Perception of Diet-Health links showed the strongest influence (highest βs), followed by Objective Knowledge About Additives. The model explained 25% of variance in Risk Perception of Additives.

Table 7.2: Summary of Multiple Regression Analysis for Variables Predicting Risk Perception of Synthetic Food Additives (N = 1023)

Predictor	*b*	*SE b*	β
Objective knowledge	-.06	.01	-.16*
Subjective knowledge	.11	.03	.12*
Trust 1	-.21	.04	-.18*
Trust 2	-.09	.04	-.07*
Food technology	-.09	.04	-.08*
Positive attitudes	-.10	.04	-.08*
Negative attitudes	.13	.04	.12*
Diet-health links	.31	.05	.18*

Note. R^2 = .25
Positive and negative attitudes refer to attitudes towards chemicals.
*p<.05

3.3 Relationship Between Risk Perception of Food Additives and Behaviour

Slightly less than half of the respondents reported avoiding food products containing E-numbers (44.3%, $n = 513$). Higher risk perceptions of food additives were related to attention to buying food products without additives ($r = .32$, $p < .05$). There was a medium-size positive correlation between the risk perception of food additives and the interest in natural food products ($r = .45$, $p < .05$). Therefore, higher risk perception implied higher interest in natural food products.

4 Discussion

We created a scale measuring objective knowledge about food additives. Some items of the scale had high rates of correct responses, particularly those referring to substances used as additives (items 11, 14, 15, 16). The highest rate of incorrect responses was observed with an item referring to labelling of additives on food packaging (item 1). More than half of the respondents did not know that additives are not always declared in terms of E-numbers; according to regulation, however, the specific name of the additive is sufficient (http://www.efsa.europa.eu/en/anstopics/topic/additives.htm). Looking out for E-numbers for some consumers might be a screening strategy to decide whether or not to buy a food product; it is however, a faulty strategy. Nearly half of the respondents thought that organic foods do not contain additives. This is not the case, as organic foods may contain natural additives. This misconception might point out that additives are equated with synthetic by many consumers; in fact, every fifth consumer in our study believed that additives are always synthetic (item 8). Substantial numbers of respondents thought that additives in our foods are a health hazard, even in people following a balanced diet (items 3, 4, 5, 6). This suggests that consumers might not be aware of the rigorous safety tests and periodic re-assessments of food additives. Further, the acceptable daily intake (ADI) levels that guide the permitted levels of additives in foods are based on a 100-fold safety margin compared to the theoretic ADIs resulting from safety tests (http://www.eufic.org/article/en/expid/basics-food-additives/). Thus, even highly exposed groups eating unbalanced diets are unlikely to be at risk from food additives. Some consumers thought that additives have negative effects on the quality of foods, such as increasing the calorie count or lowering vitamin levels (items 7, 12). There is no evidence of such effects on food quality.

There were no associations between knowledge about food additives and gender or age, which indicates that communication about food additives does not need to be targeted at a specific population. Similarly, no differences in risk perception between respondents having children living in the household and those not having children were found. This result is significant as adverse effects of additives have been related to children’s behaviour. Subjective and objective knowledge about additives influenced risk perception in opposite directions. While subjective knowledge increased risk perception of food additives, objective knowledge lowered risk perception. This finding is different from that of House et al. (2004) who found a positive correlation between subjective knowledge and acceptance of genetically modified foods. The fact that subjective knowledge is positively related to risk perception of additives is relevant for communication. Consumers who believe that they have high knowledge, and who have high risk perception of additives, might not be receptive to objective information about food additives. Thus, the perception of high subjective knowledge is a potential barrier to communication.

Trust in the producers and vendors of food products had the strongest influence on the risk perception of food additives, besides the perception of strong diet-health links. Trust in communicators and regulators had a much weaker influence on risk perception. These results suggest that, unless consumers trust the financial stakeholders of food products, efficient consumer education about food additives cannot take place. Research shows that consumer trust is based on values that consumers perceive to share with the trusted source (Siegrist, et al., 2000). Presumably, it is difficult for food producers and vendors to convince consumers of their shared values, as any such message might be perceived in a commercial context and reinforce consumers' suspicion. The critical role of trust in producers and vendors might be a reason why food additives have been perceived as a health hazard for decades despite the availability of objective information claiming their safety.

The stronger respondents perceived the links between diet and adverse health effects to be, the higher they perceived risk of food additives. This suggests that some consumers tend to reduce the link between diet and illness to a single factor, such as additives, whilst overlooking the complexity of factors that may cause an illness. The myths that circulate around adverse effects of food additives are reinforced by the way that media reports are dealt with. The common reaction to "food scares" in the media is to remove a particular product from the market. This procedure confirms consumers' negative perceptions, but it does not resolve the controversy around the safety of food additives. A better reaction would be to undertake scientific investigation and to ensure that evidence of safety and absence of adverse effects are dispersed in the media (Emerton & Choi, 2008). Further, consumers should be reminded that most illnesses have a complex, multicausal etiology.

Contrary to a previous study (Dickson-Spillmann, et al., 2011), not only positive attitudes towards chemicals, but also negative attitudes influenced risk perception of food additives. The factor Chemical Pessimism measures the expectation of a complete absence of risk in dealing with chemicals and general fear of chemicals. That these ideas influence the risk perception of food additives shows that consumers' general ideas about chemicals affect perception in a context in which chemicals are highly controlled. High control, however, is apparently not enough for some consumers. The expectation that there should be virtually no risk is against the nature of things, as it is "impossible to ensure the complete safety of any substance for all human beings under all conditions of use" (Sumner & Eifert, 2002).

We further showed that seeing benefits in food technology lowers risk perception of food additives. This is in line with previous research on the relationship between risk and benefit perception. We can assume that consumers who do not welcome food technology also see higher risks in genetically modified or nanotechnology foods. That consumers disagree in principle with adapting foods to human needs confirms the influence of more ideological components on consumers' risk perceptions and food choices (Pollard, Kirk, & Cade, 2002).

Risk perception was significantly related to consumers' interest in eating natural food products, and to having E-number content as a food purchase criterion. Thus, risk perception of food additives directly affects consumers' behaviour. This finding is highly relevant as nearly 50% of respondents reported having E-number content as a purchase criterion. With so many consumers paying attention to E-numbers, it appears particularly important to support consumers in making informed decisions by providing objective information.

Some limitations of our study need to be addressed. The regression weights of our factors would possibly be different if we had assessed the perception of benefits, diet-health links and trust more specifically with regard to food additives. Due to the nature of our survey, which dealt with additives and other food risks, questions were unspecific. Further, our sample was biased towards a higher number of female and older respondents. Swiss census data indicates a rate of 51.3% females (≥ 18 years) and an average age of 48.1 years in 2009 (Bundesamt für Statistik, 2009).

In conclusion, our study shows that consumers hold widespread misconceptions about food additives, particularly about the safety and legal aspects. Consumers who perceive close links between diet and adverse effects perceive higher risks from food additives. Because additives are a food choice criterion for many consumers, it is important to educate consumers about the objective risk emerging from food additives. The major barriers to overcome are consumers' distrust in food producers and vendors, and consumers' rating of their own knowledge.

References

Alhakami, A., & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis, 14*(6), 1085-1096.

Armitstead, A. (1998). The national health survey - consumer attitudes to health and food. *Nutrition & Food science, 2,* 95-98.

Bio Suisse. (2001). Richtlinien für die Erzeugung, Verarbeitung und den Handel von Erzeugnissen aus biologischer (ökologischer) Produktion. Retrieved from http://www.bio-suisse.ch/media/de/pdf2007/rl-ws/rl_2007_d.pdf

Bundesamt für Statistik. (2009). Statistik des jährlichen Bevölkerungsstandes (ESPOP) 2009: Definitive Ergebnisse. Retrieved from http://www.bfs.admin.ch/bfs/portal/de/index/news/publikationen.html?publicationID=4025

Connor, M., & Siegrist, M. (2010). Factors influencing people's acceptance of gene technology: the role of knowledge, health expectations, naturalness, and social trust. *Science communication, 32*, 514-538.

Costa-Font, M., & Gil, J. M. (2009). Structural equation modelling of consumer acceptance of genetically modified (GM) food in the Mediterranean Europe: A cross country study. *Food Quality and Preference, 20*(6), 399-409.

Dickson-Spillmann, M. (2008). *Consumers' mental models of the consequences of a healthy versus unhealthy nutrition*. Unpublished raw data.

Dickson-Spillmann, M., & Siegrist, M. (2008). *Consumers' perception of chemicals in food*. Unpublished data.

Dickson-Spillmann, M., Siegrist, M., & Keller, C. (2011). Attitudes toward chemicals are associated with preference for natural food. *Food Quality and Preference, 22*, 149-156.

Eidgenössisches Departement des Innern. (2007). Verordnung des EDI über die in Lebensmitteln zulässigen Zusatzstoffe (Zusatzstoffverordnung, ZuV), SR 817.022.31 vom 22.6.2007. Retrieved from http://www.admin.ch/ch/d/sr/c817_022_31.html

Emerton, V., & Choi, E. (2008). *Essential guide to food additives* (3rd ed.). Leatherhead, England: Leatherhead Publishing and Royal Society of Chemistry.

Epp, A., Michalsky, B., Banasiak, U., & Böl, G.-F. (2010). *Pflanzenschutzmittel-Rückstände in Lebensmitteln. Die Wahrnehmung der deutschen Bevölkerung – Ein Ergebnisbericht*. Berlin, Germany: Bundesamt für Risikobewertung. Retrieved from http://www.bfr.bund.de/cm/238/pflanzenschutzmittel_rueckstaende_in_lebensmitteln.pdf

European Commission. (2006). *Special Eurobarometer: Risk Issues* (238/ Wave 64.1). Retrieved from http://ec.europa.eu/public_opinion/archives/ebs/ebs_238_en.pdf

European Community. (2007). Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. *Official Journal of the European Union L 189, p. 1 of 20.7.2007.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF.

European Community. (2008a). Commission Directive 2008/5/EC of 30 January 2008 concerning the compulsory indication on the labelling of certain foodstuffs of particulars other than those provided for in Directive 2000/13/EC of the European Parliament and of the Council. *Official Journal of the European Community L 27, p.*

12 of 31.1.2008. Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:027:0012:0016:EN:PDF.

European Community. (2008b). Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control. *Official Journal of the European Community L 250, p. 1 of 18.9.2008.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:250:0001:0084:EN:PDF.

European Economic Community. (1988). Council Directive of 21 December 1988 on the approximation of the laws of the Member States concerning food additives authorized for use in foodstuffs intended for human consumption. *Official Journal of the European Community L 40, p. 27 of 11.2.1989.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav07_en.pdf.

European Economic Community. (1994a). European Parliament and Council Directive 94/35/EC of 30 June 1994 on sweeteners for use in foodstuffs. *Official Journal of the European Community L 237, p. 3 of 10. 9. 1994.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav10_en.pdf.

European Economic Community. (1994b). European Parliament and Council Directive 94/36/EC of 30 June 1994 on colours for use in foodstuffs. *Official Journal of the European Community L 237, p. 13 of 10.9.1994.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav08_en.pdf.

European Economic Community. (1995). European Parliament and Council Directive No 95/2/EC of 20 February 1995 on food additives other than colours and sweeteners. *Official Journal of the European Community L 61, p. 1 of 18. 3. 1995.* Retrieved from http://ec.europa.eu/food/fs/sfp/addit_flavor/flav11_en.pdf.

European Economic Community. (2000). Directive 2000/13/EC of the European Parliament and of the Council of 20 March 2000 on the approximation of the laws of the Member States relating to the labelling, presentation and advertising of foodstuffs. *Official Journal of the European Community L 109, p. 29 of 29.9.2000.* Retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:109:0029:0042:EN:PDF.

Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The affect heuristic in judgments of risks and benefits. *Journal of Behavioral Decision Making, 13*(1), 1-17.

Frewer, L. J., Howard, C., & Shepherd, R. (1998). Understanding public attitudes to technology. *Risk research, 1*(3), 221-235.

Frewer, L. J., Shepherd, R., & Sparks, P. (1994). The interrelationship between perceived knowledge, control and risk associated with a range of food-related hazards targeted at the individual, other people and society. *Journal of Food Safety, 14*(1), 19-40.

Gaskell, G., Allum, N., Wagner, W., Kronberger, N., Torgersen, H., Hampel, J., & Bardes, J. (2004). GM foods and the misperception of risk perception. *Risk Analysis, 24*(1), 185-194.

House, L., Lusk, J., Jaeger, S., Traill, W. B., Moore, M., Valli, C., . . . Yee, W. M. S. (2004). Objective and subjective knowledge: Impacts on consumer demand for genetically modified foods in the United States and the European Union. *AgBioForum, 7*(3), 113-123.

Kahneman, D., & Tversky, A. (1979). Prospect theory - Analysis of decision under risk. *Econometrica, 47*(2), 263-291.

Kraus, N., Malmfors, T., & Slovic, P. (2001). Intuitive toxicology: Expert and lay judgments of chemical risks. In P. Slovic (Ed.), *The perception of risk* (pp. 285-315). London, England: Earthscan Publications.

Lockie, S., Lyons, K., Lawrence, G., & Grice, J. (2004). Choosing organics: a path analysis of factors underlying the selection of organic food among Australian consumers. *Appetite, 43*(2), 135-146.

Pollard, J., Kirk, S. F. L., & Cade, J. E. (2002). Factors affecting food choice in relation to fruit and vegetable intake: a review. *Nutrition Research Reviews, 15*(2), 373-387.

Roininen, K., Lahteenmaki, L., & Tuorila, H. (1999). Quantification of consumer attitudes to health and hedonic characteristics of foods. *Appetite, 33*(1), 71-88.

Roselius, T. (1971). Consumer Rankings of Risk Reduction Methods. *Journal of Marketing, 35*(1), 56-61.

Saba, A., & Messina, F. (2003). Attitudes towards organic foods and risk/benefit perception associated with pesticides. *Food Quality and Preference, 14*(8), 637-645.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis, 24*(5), 1289-1299.

Siegrist, M., Cousin, M. E., Kastenholz, H., & Wiek, A. (2007). Public acceptance of nanotechnology foods and food packaging: The influence of affect and trust. *Appetite, 49*(2), 459-466.

Siegrist, M., & Cvetkovich, G. (2000). Perception of hazards: The role of social trust and knowledge. *Risk Analysis, 20*(5), 713-719.

Siegrist, M., Cvetkovich, G., & Roth, C. (2000). Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis, 20*(3), 353-362.

Siegrist, M., Keller, C., Kastenholz, H., Frey, S., & Wiek, A. (2007). Laypeople's and experts' perception of nanotechnology hazards. *Risk Analysis, 27*(1), 59-69.

Sparks, P., & Shepherd, R. (1994). Public perceptions of the potential hazards associated with food-production and food-consumption - an empirical study. *Risk Analysis, 14*(5), 799-806.

Stern, T., Haas, R., & Meixner, O. (2009). Consumer acceptance of wood-based food additives. *British Food Journal, 111*(2-3), 179-195.

Sumner, S. S., & Eifert, J. D. (2002). Risks and benefits of food additives. In A. L. Branen, P. M. Davidson, S. Salminen & J. H. Thorgate III (Eds.), *Food Additives* (2nd ed.). New York, NY: Marcel Dekker.

Tarnavölgyi, G. (2003). Analysis of consumers' attitudes towards food additives using focus group survey. *Agriculturae conspectus scientificus, 68*(3), 193-196.

van Dillen, S. M. E., Hiddink, G. J., Koelen, M. A., de Graaf, C., & van Woerkum, C. M. J. (2004). Perceived relevance and information needs regarding food topics and preferred information sources among Dutch adults: results of a quantitative consumer study. *European Journal of Clinical Nutrition, 58*(9), 1306-1313.

Wandel, M. (1997). Food labelling from a consumer perspective. *British Food Journal, 99*(6), 212-219.

Williams, P. R. D., & Hammitt, J. K. (2001). Perceived risks of conventional and organic produce: Pesticides, pathogens, and natural toxins. *Risk Analysis, 21*(2), 319-330.

Chapter VIII

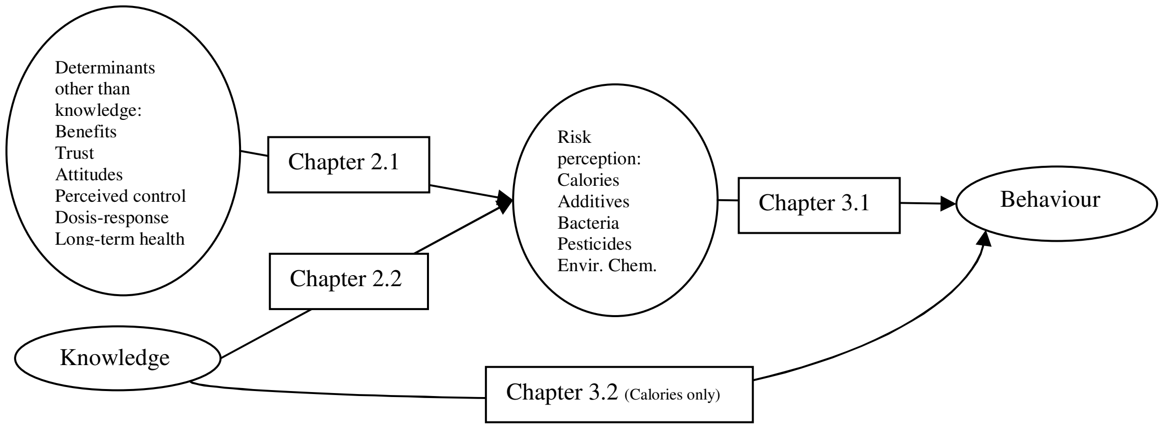
General Discussion

1 Overview of General Discussion

The present research investigated consumers' perceptions of nutritional hazards and attempted to establish relationships between perception and behaviour. One specific aim was to clarify the role of objective knowledge in hazard perception and behaviour. We aimed to develop new ideas for health communication.

This chapter intends to discuss findings across studies and hazards. In agreement with the aims of the present research that were initially defined, this chapter is divided into the following chapters: Determinants of food hazard perception; the association between risk perception, knowledge and behaviour (see Figure 8.1 for the structure of the first two chapters); and implications for hazard communication. Finally, some limitations of the present research will be addressed, research gaps for the future will be identified and a general conclusion will be drawn.

Figure 8.1: Structure of Chapters 2 and 3 of General Discussion



2 Determinants of Consumers' Food Hazard Perception

2.1 Factors Other than Objective Knowledge Influence Consumers' Food Hazard Perception

According to Chapter VI, the selection of influences on consumers' perception of different food hazards and their strength is variable. At least 26% of the variance in consumers' perception of additives and calories was explained by the assessed factors. In contrast, only 9-13% in perception of pesticides and bacteria could be explained. These findings show that other factors not assessed in Chapter VI influence consumers' perception of these two hazards.

To perceive benefits from food technology had an attenuating effect on the risk perception of all four food hazards. This finding corroborates other studies in the field of food which demonstrated the influence of benefit perception on risk perception (Alhakami & Slovic, 1994). With additives, consumers obviously recognize their benefits on sensory qualities or shelf-life. With pesticides, consumers seem to be aware of their role in supplying enough food for the population. Regarding bacteria, consumers seem to acknowledge technologies such as pasteurization. In the context of calories, consumers appear to be aware that food technology can be used to produce low-fat products. The latter finding demonstrates the technologisation of a classical lifestyle hazard: foods are no longer invariably fatty and therefore unhealthy; they can be made healthy through food technology. Calories are increasingly becoming a technological hazard. Other factors usually related to the perception of uprising food technologies, such as trust, might become more important in the perception of calories as technology is further invading this area.

Chapters VI and VII show the negative influence of social trust on the risk perception of food additives. This is in line with findings regarding GM foods (Siegrist, 2000). Factor analysis shows a split of consumers' trust in two dimensions. The fact that consumers' trust in vendors fell on the same factor as their trust in producers, and their trust in food control fell on the same factor as their trust in communicators shows that consumers do not simply distinguish those managing the risk and those communicating it, but they distinguish those concerned with making money from food and those concerned with consumer protection. This finding is in line with the theory that shared values play an important role in consumers' trust (Siegrist, 2008).

Results from Chapters III and VII support the influence of general attitudes on consumers' risk perceptions in a specific area. Consumers who had more positive attitudes towards chemicals in general (e.g. not being worried about chemicals in groundwater, thinking that society has more important risks than chemicals to deal with), perceived lower risks from additives and contaminants in foods. These findings are supportive of the halo effect. This theory states that if an object (in this context, chemicals) is judged favourably overall, it tends to be given more positive evaluations on specific dimensions (Klauer & Stern, 1992).

Chapter VI shows that perceived control over the hazard lowered risk perception of additives and calories, which is in line with Sparks and Shepherd (1994). This finding might indicate that labelling has led to an enhanced perception of control: for additives, the E-number lists and for calories, the nutritional tables on food packaging. Despite the plausibility of this finding, it seems surprising that perceived control did not influence the risk perception of pesticides. Because of the relative absence of pesticides in organic products, exposure to these substances may be reasonably controlled if consumers bought organic food. On the other hand, the present finding is in line with Chapter III which suggested that consumers feel that contaminants (including pesticides) cannot be controlled through eating natural foods. More research is needed to find out why consumers hold this perception.

While the factors mentioned above (benefit perception, trust, general attitudes and control perception) corroborate findings from previous research or extend them to new hazard areas, the present research also demonstrates the role of previously unexplored influences on food risk perception. Interestingly, these influences were often observed in relation to food additives. This is possibly due to the fact that additives have been a topic for quite a long time, therefore consumers have some experience with them and developed their own hazard conceptions. Chapters III and VII, for example, show the influence of consumers' understanding of dose-response relationships or of the belief in a close relationship between nutrition and vague illness symptoms on the risk perception of food additives.

Chapter VI also illustrated the influence of people's readiness to make long-term sacrifices for their health on the risk perception of calories. This factor was measured through items such as “I already do everything I can to prevent a chronic disease in the future”. To our knowledge, the factor Readiness for Long-Term Health Efforts was operationalised for the first time in this study and the expected positive relationship to risk perception of calories was observed. There is also a positive effect on the risk perception of bacteria, which was unexpected as bacteria are more associated with acute infections than diseases threatening the future.

2.2 Objective Knowledge Attenuates Hazard Perception of Pesticides and Additives

Because of its traditional significance in the study of risk perception (cf. lay-expert models of risk perception), knowledge received particular attention in the present work. Chapters VI and VII showed the attenuating influence of objective knowledge on the risk perception of pesticides and additives. The role of knowledge in risk perception can be embedded in dual-process theories of thinking (e.g. Epstein, 1994). These theories postulate two competing systems that determine risk perception, the analytic and the experiential system. The experiential system is based on affect, associations, images, and narratives. The analytical system is based on logical reasoning, abstract symbols, and evidence. According to these theories, having higher knowledge indicates the dominance of the analytic system in risk perception.

Chapter VI suggests that objective knowledge does not play a role in the risk perception of bacteria and calories. An explanation of this finding might be that the influence of knowledge on risk perception of these two hazards can work in two different directions. Consumers with higher knowledge of calories and bacteria might be more aware of the unavoidable nature of these hazards; many foods naturally contain harmful bacteria and calories, and consumers can reduce, but not eliminate, the health risk associated with these hazards. Keeping these facts in mind, greater knowledge of bacteria and calories could increase risk perception due to the awareness of the limited possibilities to influence these hazards, but greater knowledge could also reduce risk perception due to the awareness of possibilities to reduce these hazards. More data analysis is needed to evaluate these assumptions.

According to Chapter VI, subjective knowledge plays a positive role in the risk perception of additives and calories. The more people believe to know about these hazards, the higher their risk perception. Depending on the hazard, this is a favourable trait or a barrier to health communication. With additives, a hazard characterized by low objective risk, people with a high risk perception and high perceived knowledge may not be receptive to hazard information and might believe that they already know all about additives. In the case of calories, which according to the rising prevalence of nutrition-associated disorders are an effective health hazard, higher subjective knowledge implies higher risk perception. This is in line with health authorities’ current concerns of making consumers aware of the health risks from calorie overconsumption.

3 Nutritional Hazard Perceptions, Knowledge and Behaviour

3.1 Perceptions of Additives, Pesticides and Bacteria and Environmental Chemicals are Related to Behaviour

Chapters III, VI and VII showed that the risk perception of different food hazards was correlated with risk-related behaviour. Higher risk perceptions of bacteria lead to better hygienic behaviour and higher risk perceptions of pesticides to a higher likelihood of washing fruit and vegetables before consumption. Further, higher risk perceptions of additives implied paying attention to additives on food packaging and having a higher natural diet interest (which is measured by items directly referring to behaviour, e.g. “I try to eat foods that do not contain additives”).

Chapter II illustrated a surprising relationship between hazard perceptions and exposure to phthalates through diet. While the absence of a correlation between perception and phthalate exposure would have been an interesting story, the study even revealed a positive relationship between risk perception of chemicals in diet, natural and healthy diet interest, and phthalate exposure through food consumption. This shows that with environmental chemicals like phthalates, consumers’ attempts to reduce their risk exposure are in vain. Phthalates represent a hazard that is completely in the hands of the chemical industry, food producers, food transport and storage providers, and last but not least, researchers investigating their harmful potential and occurrence. With environmental chemicals such as phthalates, for consumers there are no ways of influencing their exposure. Consumers cannot be told to stop eating cereals or fruit altogether. To protect consumers, it is of great importance to keep monitoring food products for environmental chemicals, and to continue the search for the routes via which these chemicals may enter foods.

3.2 Nutrition Knowledge Shows Small, but Consistent Relationships with Behaviour

In both Chapters IV and V correlations between nutrition knowledge and food consumption were observed for only about one-third of the foods included in the food frequency questionnaire. This illustrates the limits of knowledge in food consumption: knowledge seems to be relevant for the consumption of some foods, but on the consumption of many other foods, knowledge simply does not have a relevant influence. Limits of knowledge in nutrition behaviour were also observed with regard to the effect sizes, which were small- even when procedural nutrition knowledge was measured. Effects of knowledge were higher with regard to foods defined as healthy, rather than those defined as unhealthy. This result shows that enhancing knowledge is likely to lead to a healthier eating pattern, rather than to a less unhealthy one.

We conclude that despite a consistent influence of nutrition knowledge on food consumption, many other factors also influence consumption. In this context, a very interesting view on health behaviour has been proposed by Resnicow and Vaughan (2006). These authors criticize the commonly used cognitive-rational paradigm (as used, for example, in the present work) in which health behaviour change is conceptualized as a process linearly determined by changes in knowledge, attitudes and intentions. The authors start from the observation that only minor variance in behavioural variance has been explained by these determinants; the rest of the variance has been ascribed to random errors. The authors argue that this understanding of health behaviour does not do justice to its complexity. They suggest that chaos theory might provide a more useful view on health behaviour. Chaotic systems are impossible to predict, sensitive to initial conditions, they involve multiple component parts that interact in a nonlinear fashion, and the result of a chaotic system is greater than the sum of its parts. The authors propose that the unexplained variance usually attributed to error may actually be the chaotic component of health behaviour. This chaotic component may include 5-, 10- or 15-way interactions of within and between-individual variables. Health behaviour change, rather than linear, is a quantum event resulting from a surge of motivation that does not have one or several, but infinite predictors that interact with each other. The authors see the linear and chaotic paradigms not as mutually exclusive, for the first may “provide the fertile soil on which chaotic events may sprout”(p. 6).

Altogether, the present discussion suggests the conclusion that knowledge is a factor of nutrition behaviour, but its role is limited and there is little evidence that higher linear correlations between knowledge and behaviour than the ones observed in the present work can be observed in the future. Chaos theory might provide an interesting approach to nutrition behaviour in the future.

4 Recommendations for Risk Communication

The present research suggests that in the planning of health risk communication, two steps need to be undertaken. First, consumers' current hazard perceptions and related behaviours need to be investigated. This can be done using public mail surveys, such as those performed in our research. Based on these, the purpose of hazard communication can be determined: Do consumers need to be informed about an existing nutritional hazard that they do not seem aware of, or do consumers' present strong concerns about a minor hazard need to be addressed? As an example, in the area of bacteria, consumers seem to not be aware that a major contributor to health risk is located in their own home, hence their awareness of this fact should be addressed. In contrast, consumers with strong concerns about food additives should be reassured that the additives in food are not a health risk for most consumers- at least no more than some naturally occurring substances. The challenge for nutritional hazard communicators is to avoid panic, resistance and suspicion among consumers.

The present research suggests that objective knowledge, historically the central factor of risk communication, plays a limited role in consumers' perception of food hazards. Objective knowledge was related to perception of pesticides and additives, and to consumption of some healthy or unhealthy foods, but relationships were not very strong. No relationships between knowledge and the perception of bacteria could be found. In contrast, the present work identified a number of factors other than knowledge that influenced risk perception, especially in the context of the technological hazards additives and pesticides. We therefore suggest that future hazard communication aims to fill the gaps in consumers' hazard knowledge whilst taking into account the other factors. Their inclusion is crucial in order to create optimal conditions for hazard information transfer.

In the case of food additives, it appears important to inform consumers of the labelling rules on food packaging, on the occurrence of additives in organic food and on the fact that not all additives are synthetic. Also, it should be emphasised that illnesses such as Alzheimer's or asthma have a complex aetiology that cannot be ascribed to the consumption food additives alone. At the same time as transferring this information, the benefits of food additives (e.g. to protect food from spoilage), and consumers' possibility to control their exposure to food additives should be emphasised. Food producers and vendors are advised to stress their shared values with consumers in order to gain trust.

Regarding pesticides, more research is needed to understand which factors influence consumers' risk perception. The present research suggests that consumers' level of objective knowledge about pesticides should be enhanced. Pesticide risk communicators should be aware that their communication might positively influence consumers' concerns about pesticides. Thus, not only information about the possible risks, but also careful explanation about why pesticides are used should be transmitted.

Regarding bacteria, more research is needed to identify the factors influencing consumers' risk perception. Other research suggests that many consumers are unaware that the highest risk of contracting foodborne disease is located in their own home (Woodburn & Raab, 1997).

In the case of over and malnutrition, the present work suggests that rather than being focused on single foods or components, consumers should be provided with a holistic picture of healthy nutrition. This includes, for example, enhancing consumers' awareness of the food pyramid. Consumers need more guidance on how to eat healthily, and not so much on what to eat. According to the present research, this approach might affect nutrition behaviour more than teaching consumers about the ingredients of different foods.

5 Limitations

There are some theoretical and methodological limitations to the present research that should be addressed.

The variable Risk Perception had a very central role, being used as a mediator between other perceptions or attitudes, and behaviour. This was based on theories promoting perceived risk as a guide of behavioural decisions (Kahneman & Tversky, 1979). It is, however, plausible that risk perception does not always mediate between other attitudes or perceptions and behaviour. These attitudes or perceptions might influence behaviour in their own right. For example, concerns about environmental pollution might lead consumers to reject conventionally produced food products without perceiving health risks from pesticides (Wandel, 1994).

Questionnaires were used to collect data for all studies. This method is highly useful when large sample should be studied. Questionnaires are, however, not free of methodological problems. The most important of these problems refers to the context of responding. In mail surveys, respondents see individual questions as part of a larger set of questions as they can look ahead and preview questions (de Vaus, 2002). Thus, items might be answered in a different order than intended by the researcher. Further, the high number of variables used to answer the present research questions required rather lengthy questionnaires, possibly leading to tiredness and distractibility with respondents and affecting data quality.

Self-reported behaviour was assessed as an outcome of risk perception. This way of measuring behaviour is highly efficient as behaviour of large groups can be measured. Studies point out, however, that self-reported behaviour measures are liable to over- or underreporting (Heerstrass, Ocke, Bueno-de-Mesquita, Peeters, & Seidell, 1998; Kristal, Feng, Coates, Oberman, & George, 1997), a bias at least partly explained by people's tendency to give socially desirable responses.

Finally, our data was collected in the Swiss German population. Large samples were used in order to draw general conclusions. It remains, however, open whether and how far the present findings and conclusions may apply to the populations of other countries. Studies such as the Eurobarometer indicate that countries differ in their concerns about various food risks (European Commission, 2006).

6 Directions for Future Research

The present research is based on a deterministic view of nutrition behaviour. Methods used to evaluate research questions included bivariate correlations, regression analyses, or analyses of variance. The idea of a linear relationship between predictors and nutrition behaviour has been criticised by exponents of the chaos theory of health behaviour. According to this theory, countless interactions between predictors lead to a specific nutrition behaviour. This perspective seems to do more justice to the complexity of our social and natural environment. Therefore, we propose that future research pay greater attention to the interactions between predictors and to non-linear relationships between predictors and nutrition behaviour. Such an approach requires interdisciplinary collaboration, non-linear statistical methods and longitudinal data in order to understand the dynamics of nutrition behaviour change (Baranowski, 2006; Resnicow & Vaughan, 2006).

Given the limitations regarding the assessment of behaviour in the present research, it appears necessary to shift to a more ecological approach that includes assessments of effective behaviour. Older methods such as food diaries or recalls, but also more recent methods such as fake food buffets, records of consumers' loyalty cards or eye-trackers could be used to re-evaluate the present research questions. Obviously, such assessments could not be undertaken at the same large scale as the questionnaire research in the present work due to their higher cost.

The present research has made a number of recommendations for nutrition communication. The logical continuation of this work therefore would be to test the efficiency of these recommendations. This could, for example, be undertaken in the shape of experiments in which variables such as information content about food additives, trustworthiness of communicators or emphasis of benefits would be manipulated while risk perception and assessments of knowledge would serve as outcome measures.

7 Final Conclusion

The present research shows that consumers' perception of nutritional hazards is determined by many influences, ranging from social trust to misconceptions about dose-response relationships. These influences vary according to the characteristics of the hazard in question. Objective knowledge, traditionally a key factor of risk perception and behaviour, is only one influence of many, and its strength should not be overestimated. In the future, non-linear approaches to nutrition behaviour will represent an attractive research branch.

The present research is seen as a contribution to basic research of consumers' nutritional hazard perception. From our findings, we attempted to derive implications for future nutrition hazard communication. Our main insight is that there is no recipe that is valid for all hazards. Hazard communication, therefore, needs to be individually adapted to the hazard in question. Future research might move into a more applied direction and validate our findings in the field.

References

Alhakami, A., & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis, 14*(6), 1085-1096.

Baranowski, T. (2006). Crisis and chaos in behavioral nutrition and physical activity. *International Journal of Behavioral Nutrition and Physical Activity, 3*(27).

de Vaus, D. (2002). *Surveys in social research*. Oxon, England: Routledge.

Epstein, S. (1994). Integration of the cognitive and the psychodynamic unconscious. *American Psychologist, 49*, 709-724.

European Commission. (2006). *Special Eurobarometer: Risk Issues* (238/ Wave 64.1). Retrieved from http://ec.europa.eu/public_opinion/archives/ebs/ebs_238_en.pdf

Heerstrass, D. W., Ocke, M. C., Bueno-de-Mesquita, H. B., Peeters, P. H. M., & Seidell, J. C. (1998). Underreporting of energy, protein and potassium intake in relation to body mass index. *International Journal of Epidemiology, 27*(2), 186-193.

Kahneman, D., & Tversky, A. (1979). Prospect theory - Analysis of decision under risk. *Econometrica, 47*(2), 263-291.

Klauer, K. C., & Stern, E. (1992). How attitudes guide memory-based judgments - A 2-process model. *Journal of Experimental Social Psychology, 28*(2), 186-206.

Kristal, A. R., Feng, Z. D., Coates, R. J., Oberman, A., & George, V. (1997). Associations of race/ethnicity, education, and dietary intervention with the validity and reliability of a food frequency questionnaire - The women's health trial feasibility study in minority populations. *American Journal of Epidemiology, 146*(10), 856-869.

Resnicow, K., & Vaughan, R. (2006). A chaotic view of behavior change: a quantum leap for health promotion. *International Journal of Behavioral Nutrition and Physical Activity, 3*(25).

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis, 20*(2), 195-203.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science & Technology, 19*(11), 603-608.

Sparks, P., & Shepherd, R. (1994). Public perceptions of the potential hazards associated with food-production and food-consumption - an empirical study. *Risk Analysis, 14*(5), 799-806.

Wandel, M. (1994). Understanding consumer concern about food-related health risks. *British Food Journal, 96*(7), 35-40.

Woodburn, M. J., & Raab, C. A. (1997). Household food preparers' food-safety knowledge and practices following widely publicized outbreaks of foodborne illness. *Journal of Food Protection, 60*(9), 1105-1109.

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Curriculum vitae

Maria Dickson-Spillmann was born in 1980. In 2000, she acquired her Maturity certificate from the Kantonsschule Limmattal in Urdorf, Switzerland. She then studied Psychology, Psychopathology and Criminology at the University of Geneva and the University of Zurich. During her studies, she completed five months of internships as a student psychologist in two psychiatric institutions. At the end of 2006, she graduated with an MSc in Psychology from the University of Zurich. Following this, she spent half a year living and working in Plymouth, UK as a research assistant for the Respiratory Research Unit of the Peninsula Medical School.

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